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(Continued from page 155.)

19thly. I say nothing respecting the effect (if any) produced by the decomposition of the carbonic acid gas that is formed by the carbon of the coal, uniting to the oxygen of the ore, and of the moisture. I am not equal to the investigation, for want of more precise knowledge of fact. I must say the same as to the effect produced by the carbonic acid gas driven off from the limestone, to the amount of 44 per cent. in weight. I do not know that this is again decomposed. I am fully aware of M. Clouet's and Mr. Mushet's experiments, and I know too, that carbonic acid gas contains 28 3-4 per cent. of pure carbon or charcoal, but I cannot yet apply them to a smelting furnace. I shall remark upon this when I come to the subject of steel. For the same reason I leave untouched any chemical theory as to the combinations that may be formed by the Potassium of the charcoal ashes, or by the Calcium of the lime, the Aluminum of the clay, or the Silicum of the siliceous earths. I subjoin Mr. Davy's re-

marks, but I am not at present qualified to apply them to practical purposes.

"Iron is capable of combining with Potassium and Sodium; these alloys are more fusible and whiter than iron, and effervesce copiously in water. There is great reason to believe that alloys may be formed of iron and the metals of the earths. *Cast iron*, which is produced by fusing iron ores with pitcoal, during its conversion into malleable iron, affords but one fourth of its weight of a glass, which consists of silex, alumine, lime, oxide of iron, and oxide of manganesum. In the process for reducing cast iron into malleable iron, called *blooming*, the iron, after being fused in a forge by a fire of charcoal, is hammered, whilst in a soft state, on an anvil, by a large hammer worked by water; a vivid combustion, which seems to be connected with the formation of the glass and the oxides, takes place on the surface of the mass: that the earths are formed by the oxidation of metals combined in the cast iron seems probable from the circumstance of the combustion; and the idea is confirmed by the distinct metallic character of cast iron; it is white, crystallized, and has all the appearance of a perfect alloy. Specimens of cast iron usually contain likewise sulphur and carbon."

20thly. I close these remarks by the following quotation from Mushet—5 Ph. Mag. 366.

On the relative Proportions of Coals and Iron-Stones used at the Blast-Furnace, and of their proper Application to Use. By Mr. DAVID MUSHET, *of the Clyde Iron-Works. Communicated by the Author.*

IN the smelting operation a just proportion and association of materials and mechanical construction ought to be blended in order to produce the best possible effects. Under the former, are comprehended the cokes, iron-stone, limestone, and blast; by the latter is understood

the furnace, the power of the blowing-machine, or the compression and velocity under which the air is discharged into the furnace, and the genius or mechanical skill of the workmen. According to this division, I shall endeavour to point out the very various effects which disproportion in any case produces, and *vice versa*.

In the preceding papers, the coal and iron-stone have been traced through their various stages of preparation, and that stage pointed out in which they were most suitable for the profitable manufacture of the metal. It will be necessary to carry along with us this fact, that in the exact proportion which the quantity of carbon bears to the quantity of metal in the ore, and its mixtures, so will be the fusibility, and of course the value of the pig-iron obtained. The importance of this truth will still farther appear, when we consider the very various qualities of pit-coal, the different proportions of carbon which they contain, and the various properties attached to every species of this useful combustible.

Among the many strata of coal which I have distilled, some I have found to contain 70 parts in the 100. This large proportion is peculiar to the clod-coal, used at some of the iron-works in England; and justly preferred, for the purpose of manufacture, to the purest and hardest variety of splint-coal. The latter I have found to average from 50 to 59 parts of carbon in the 100; and the soft, or mixed qualities of coal, from 45 to 53 parts. Such various proportions of carbon plainly point out that the operations to be followed at each individual iron-work ought not to rest upon precedent, unless borrowed from those works where exactly the same quality of coal is used. This analysis also, lays open part of the source from whence originates the widely different quantities of metal produced *per* week at various blast-furnaces, and the great disproportions of ore used to different coals.

Experience has shewn that the three qualities of coal just mentioned, will smelt and give carbonation to the following proportions of the same species of torrefied iron-stone :—

112 lb. of clod-coal cokes will smelt - -	130 lb.
112 lb. of splint-coal cokes will smelt - -	105 lb.
112 lb. mixed soft and hard coal cokes will smelt	84 lb.

Let the iron-stone be supposed in the blast-furnace to yield 40 *per cent.* then we find that the 1-20th of a ton of the respective qualities of cokes will smelt and carbonate the following proportions of iron, *viz.*—112 lb. clod-coal cokes, 130 lb. iron-stone, at 40 *per cent.* = 52 lb. iron; 112 lb. of splint-coal cokes, 105 lb. of the stone = 42 lb. of iron; and 112lb. soft and hard coal cokes, 84lb. of the iron-stone = 33, 6 lb. of iron. We then have for the quantity of metal produced by one ton of each quality of cokes :

Clod-coal	52	× 20	=	1040 lb.
Splint ditto	42	× 20	=	840 lb.
Mixed ditto	$33\frac{6}{10}$	× 20	=	702 lb.

This furnishes a datum, whereby we easily obtain the quantity of the various cokes necessary to produce 1 ton of carbonated crude iron by common proportion: for if 1040 lb. of metal are produced by 1 ton, 2240 lb. of clod-coal cokes, the quantity of the same cokes requisite for the production of 1 ton, or 2240 lb. of metal, will be :

		T.	*C.*	*Q.*	*lb.*
	4824·6 lb. =	2	3	0	8
Splint coal cokes	840 : 2240 : : 2240 : 5973·3 lb. =	2	13	1	9
Mixed ditto	702 : 2240 : : 2240 : 7147·5 lb. =	3	3	3	7

If to the quantity of cokes necessary to manufacture 1 ton of crude iron, we add the quantity of volatile matter driven off in the process of charring, which may be thus estimated upon the average of each quality :—

Clod coal	$\frac{3}{8}$ or $37\frac{1}{2}$ *per c.*	produce in cokes	$\frac{5}{8}$	*a* $62\frac{1}{2}$ *per c.*
Splint coal	$\frac{4}{8}$ — 50	——	$\frac{4}{8}$	or 50
Mixed coal	$\frac{5}{8}$ — 62,5	——	$\frac{3}{8}$	— $37\frac{1}{2}$

Then, for the quantity of the respective coals used in the raw state, we have the following results in proportion:—

		T.	*C.*	*Q.*	*lb.*
Clod coal	5 : 4824·6 :: 8 : 7719$\frac{3}{4}$ =	3	8	2	19
Splint coal	4 : 5973·3 :: 8 : 11946 =	5	6	2	18
Mixed coal	3 : 7147·1 :: 8 : 19158$\frac{2}{4}$ =	8	11	0	16

These great disproportions of quantity, used to fabricate 1 ton, or 2240 avoirdupois pounds of the same quality of crude iron, will convey a striking and impressive idea of the multifarious qualities of coal which may be applied and made to produce the same effects. It should also convince the manufacturer that the study and analysis of his own materials is the first and radical approach to true knowledge, and certainty of operation. Divest him of this knowledge, and view him guided by the *customs* and *rules* prevalent at another manufactory, where the coals and ores may be as different as has been already mentioned, and we will no longer wonder at the uncertainty of his results, and the numberless errors of his direction.

Before I enter into the practical discussion of the application of coal, I beg leave to indulge myself in the following calculations:—We have already seen that the production of 2240 lb. of carbonated crude iron requires 4824 lb. of clod-coal cokes; these may be averaged to contain 4·5 *per cent.* of ashes, which, deducted from 4824, gives 4607 lb. of carbon used for 1 ton of metal: this sum, divided by 2240, farther gives, for 1 lb. of cast iron thus manufactured, 2·056 lb. of carbon.

We next find that 2240 lb. of the same metal requires of splint-coal cokes 5973·3 lb.; we farther find, from a table of the analysis of coal, furnished in a former paper, that 100 parts of the raw coal contained 4·2 parts of ashes. As it is there stated to lose 50 *per cent.* in char-

ring, 100 parts of cokes will contain 8·4 of ashes; and 8·4 *per cent.* deducted from 5973·3, gives 5472 lb. of carbon. This again, reduced by 2240 lb. gives for each lb. of metal manufactured, 2·442 lb.

Again, 7147·1 lb. of cokes produced from soft mixed coals are consumed for every ton of 2240 avoirdupois pounds of crude iron produced; every 100 parts of the same coals contain 3·3 parts of ashes; and 100 parts of cokes contain nearly 6·5 *per cent.* of ashes, which, deducted from 7147·3, gives 6672·6 of carbon, which divided by 2240, gives, for the quantity used for 1lb. of cast iron, 2·978 lb.

From these calculations it appears, that 2240 lb. of carbonated iron, requires of carbon from clod-coal 4607 lb.; of carbon from splint-coal, 5472 lb.; and of carbon from mixed coal, 6672 lb.: that 1 lb. of carbonated iron requires of carbon from clod-coal cokes 2,056 lb.; from splint, 2,442 lb.; from mixed, 2,983 lb.: and that carbonated crude iron may be obtained when widely different quantities of carbon have been consumed.

In seeking for a solution of the latter fact, we must have recourse to the different degrees of inflammability of the carbon, according to the various laws of continuity imposed upon it in its fossil construction. It can easily be conceived, that, owing to this structure, and the nature of the interposed ashes, the particles of carbon of some cokes will be more easily oxygenated than those of others; in the same way that we find splint-coal, when exposed to ignition in contact with open air, affords 1-3d of more cokes than are obtained from soft mixed coals, though the latter, when distilled, yields more pure carbon than the former.

By experiment it is proven, that 100 grains of carbonic acid gas is composed of 72 parts of oxygen united with 28 parts of carbon: if the quantity of carbon of clod coal,

viz. 2·056 lb. used for the manufacturing of every pound of cast iron is reduced to grains, we will find it to consist of 14392 grains; this, divided by 28, gives the acidifiable principle of 514 × 100 = 51400 grains of carbonic acid gas;* hence, as 1 cubic foot of this gas, at 29·84 of barometrical pressure, and 54·5 of temperature, weighs nearly 761 grains, we find, that in the formation of every pound of cast iron $\frac{51400}{761} = 67{\cdot}54$ cubical feet of carbonic acid gas will be formed, and in the production of 1 ton of metal, the astonishing quantity of 151289·6 cubic feet. This quantity, however incredible it may seem, is only what would be formed under the above pressure, and at the above temperature: when we take into the account the high temperature at which the decomposition and recombination are effected, with the consequent increase of elastic force and of volume, our ideas are almost unable to commensurate the sum of the gas hourly formed, and thrown off, ignited to the highest degree of heat.

If the same mode of calculation be adopted with the other qualities of coal, we shall have the following results:—

For the splint coal 2,442 lb. or $\frac{17094}{28} = 610{,}5 \times 100$

* This is supposing, for the moment, that the whole of the carbon is oxygenated, either by the oxygen contained in the ore, or obtained from the discharging-pipe by the decomposition of the atmospheric air; this, however, is not strictly true, as the metal takes up a small portion, by weight, of the carbon; and when, by accident, moisture has been introduced into the furnace, either through the medium of the blast, or of the materials, its decomposition furnishes a portion of both oxygen and hydrogen, which may dissolve, and also carry off, a part of the carbon. Atmospheric air being found to hold water in solution, a small quantity of hydrogen will, even in the driest weather, be present in the blast-furnace. M.

$= 61050$ grains of carbonic acid, which gives $\frac{61050}{761} =$ 82,85 cub. feet for 1 lb. and $82,85 \times 2240 = 185,584$ cub. feet for 1 ton. For the mixed coal or $2,983\ \frac{20881}{28} = 710 \times 100 = 71000$ grains carbonic acid; that is, $\frac{71000}{761} = 93,3$ cubical feet for 1 lb. and $93,3 \times 2240 = 208,992$ cubical feet for 1 ton. By the same calculation we may attain a pretty accurate notion of the quantity of atmospheric air necessary to produce 1 lb. or 1 ton of cast iron; an average of the three varieties of coal will be sufficiently accurate for this purpose; thus $\frac{14392 + 17094 + 20881}{3} = 17455\frac{2}{3}$ or 2,4935 lb. of carbon are consumed upon the average of each pound of pig iron: this is found to produce of carbonic acid gas $\frac{17455\frac{2}{3}}{28} = 62{\cdot}341 \times 100 = 62{\cdot}30041$ grains; which again divided by 761, the grains in one cubic foot, gives 81·86 cubic feet for the gas discharged in manufacturing one pound of cast iron. As carbonic acid contains, as has already been noticed, 72 parts of oxygen in 100, then we have for the quantity of oxygen gas 100 : 72 : : 62300·41 : 44856·29 grains oxygen gas; and as, at the ordinary temperature and pressure of the atmosphere, a cubic foot of oxygen gas weighs 591 grains, we find 44856·29 divided by 591 = 75·89 cubic feet of oxygen gas necessary to form the acidifying principle of 81·86 cubic feet of carbonic acid gas; and that the same quantity of oxygen gas is necessary to the production of one pound of carbonated crude iron. This leads us to the following statement for the quantity of atmospheric air used during the same operation; first premising that the constituent parts of atmospheric air are nearly 73 of azote and 27 of oxygen gas; of atmospheric air then necessary, we have 27 : 100 : : 75·89 : 281 cubic feet.

I shall now proceed from mere calculation to matter of fact, and attempt to prove the correctness of the former by the approximation of the latter to its results. Let a blast-furnace be supposed to produce 20¼ tons of pig-iron *per* week, = 45360 avoirdupois pounds; this, divided by days, hours, minutes, and seconds, gives *per* day 6480 pounds, *per* hour 270, *per* minute 4½ lb., and *per* second 525 grains.

From this it is evident that 1 lb. of cast iron is produced in 13$\frac{11}{100}$ seconds: experience has shewn that a blast-furnace, producing, in any of the above periods, the respective quantity of metal, requires a discharge of air *per* minute nearly equal to 1350 cubic feet; this, divided by 4,5 lb. the quantity produced *per* minute gives, for 1 lb. iron, 300 cubic feet. The quantity, by calculation, we have seen to be 281 cubic feet—difference 19: a sum no way considerable when we reflect upon the inequality of the movements of a blowing machine, and when it is recollected that some allowance ought also to be made for what air may pass through the furnace undecomposed, or may be lost at the place of entrance.

From this coincidence of theory with practice, we cannot help admiring the rigorous principles on which the Lavoiserian system is founded; nor are we less pleased to find, that, small as the operations of the chemist may be, yet they are a just epitome of what takes place in the philosophy of extensive manufactories. The following table exhibits the quantity of carbon which may be used upon an average, with the relative quantity of carbonic acid formed, and air used:

In the manufacture of	1 lb.	— 1 ton of iron,
The pure carbon requisite is	2·49	— 5585·44 lb.
Carbonic acid formed -	81·86	— 183366·40 cub. feet.
Oxygen gas used -	75·89	— 169993.60 cub. feet.
Atmospheric air employed	281·00	— 629440·00 cub. feet.

From the foregoing particulars upon coal may be learned how much is dependent upon the native construction of coal and its constituent parts; I shall next advert to the effects produced by its improper preparation.

When coals intended for the blast furnace are sufficiently charred, they ought, in point of colour, to be of a silver grey; their fracture will appear lamellated and porous if splint coals have been used; softer coals form themselves into branches slightly curved, and, when properly prepared, are always very porous. I have frequently found that the better the cokes were charred, the more water they will absorb. Coals half burnt do not take up half so much water, because their fracture continues in part to be smooth and less porous than when thoroughly burnt.

When half prepared cokes are introduced into the furnace, the metal formerly carbonated will lose its grey fracture, and approach to the quality of oxygenated iron. Their presence is easily detected by the unusual quantity of thick vapour arising along with the flame. Besides, the water and sulphur, which raw coals introduce into the furnace, and which always impair the quantity of carbon by the various solutions effected by the presence of o ygen, hydrogen, &c. the fitness of the coal for combustion, and the support of the ore, is much diminished by this second course of ignition and disengagement of bitumen. The pressure of the incumbent ores also, fracture and reduce the cokes into small pieces, which produce a considerable portion of coke-dust; this is partly carried to the top of the furnace before the blast; sometimes below it appears in immense quantities, ignited to whiteness, and liquid as sand. Coal thus detached from the mass, exposed to the action of a compressed current of air, is unfit for conveying the carbonic principle to the metal; and as it frequently belongs to the just proportion of charcoal

necessary to smelt the ores, and to carbonate their iron, its loss must be felt, and the quality of iron impaired.

When cokes of any quality are exposed to a moist atmospheric, so as to absorb water, their effects in the blast-furnace become much reduced, and the presence of the water is productive of the most hurtful consequences in the production of carbonated crude iron. I have found, by repeated experiment, that 1 lb. of well prepared cokes will, when laid in water, take up $1\frac{3}{4}$ ounces in the space of half an hour; at this rate, a basket of cokes weighing 80 lb. saturated with water, will contain 140 ounces of water, or 8 3-4ths lb. If the charge contains six baskets, then we see that upwards of 50 lb. of water is introduced regularly along with the charge, furnishing an additional quantity of oxygen equal to 42 1-2 lb., and of hydrogen equal to 7 1-2 lb.: it frequently happens that the cokes contain a larger portion of water than is here stated. When cokes thus surcharged are introduced in quantity into the blast-furnace, the quality of the metal is not always instantaneously changed, and frequently the colour and form of the cinder remain long without any great alteration. The contact of wetted cokes with the ore is first seen by the great discharge of pale-blue gas, with the whiter flame at the top of the furnace; next, the accumulating oxyde upon the surface of the pig when consolidating indicates their presence. Iron thus oxygenated, frequently exhibits while fluid, that agitation and delicate partings peculiar to carbonated metal: the remelting of this iron is never attended with advantage, and is always unprofitable to the founder.

From the properties assigned to pit-coal in this and in former papers, the following facts may be deduced:—That charcoal is the basis of the manufacture of crude iron; that its proper application produces the most valuable qualities of pig-iron; that, by diminishing its relative

proportion, or contaminating its quality by heterogeneous mixtures, the value and fusibility of the metal is lost; but that, by a proper increase, and always in proportion to this increase will the fusibility and value of the iron be mended. From the whole, an important lesson may be learned of the pernicious effects of water in the furnace, and how absolutely necessary it is to prepare the cokes without using water, either to damp the fires, as in the usual mode, or to cool the cinders obtained from the tar kilns, to prevent their consuming in the open air: in all this hurtful operation, considerable quantities of water become fixed in the cokes, which require a very great degree of heat to expel.

The preparation of iron-stone has already been fully attended to, and the phenomena which it exhibits under every stage minutely described. In consequence of various experiments we are authorised to draw the following conclusions: That when pure calcareous iron-stone is used, it admits of having the local quantity of cokes diminished; that argillaceous requires a larger portion than the calcareous genus; and that siliceous iron-stone requires a greater proportion of fuel than any variety of the former genera. We have also seen that fusibility, either connected with strength or otherwise, is derived from the mixture of the ores; and that excessive brittleness, intimately connected with infusibility, is also derived from the same source. From a review of these facts, we are forcibly impressed with the importance of combining the prepared iron-stones with proportions of fuel suited to their various natures, in order to produce all the varieties of crude iron with the greatest possible œconomy. Contemplating farther the same subject, it is easy to be conceived that a want of knowledge of the component parts

of iron-stones, and the effects which individually they produce, must lead to great uncertainty of operation in the smelting process, wherein the beautiful œconomy of nature, and even real property, will be often unprofitably sacrificed to precedent.

Besides the above causes of alteration, dependent upon mixtures of the earths, the existence of oxygen in various quantities in the ores ought never to be overlooked in proportioning the cokes to the iron-stone. This powerful agent whose form and substance constantly eludes our vision; whose existence is only ascertained by the wonderful changes produced by its various combinations with the iron; and whose presence in the same iron-stone, in various quantities, may produce such variety of result as to characterise the ores, as containing *good* or *bad* iron, surely forms the most interesting mixture which ores or iron-stones possess. It will be a momentous epoch in the manufacture of iron when the existence of such a principle shall be fully admitted by the manufacturer, and its agency, from certain visible effects produced, adopted to explain its accompanying phenomena. Till that period he will not perceive the utility of ascertaining the quantity of oxygen, and devising œconomical methods of taking it from the ore. An attention to this powerful principle can alone root out those prejudices so inimical to the real interests of the manufacturer, and which seem to glance at Nature, as having improvidently combined her most useful metal with mixtures which could resist the ingenuity of man, or set his comprehensive intellect at defiance. In the progress of this great inquiry, is it not possible that the present expensive exertions may in part be superseded? Is it not possible, that, by laying open the sources of information to individuals at large, a greater mass of intellect may engage in the practice of this art? While the present extensive and lofty buildings are necessary, the business is

entirely confined in the hands of men of great capital: the extent of their manufactures require that a large tract of country be devoted to their supply; a natural consequence is, that innumerable small tracts of land are overlooked, or held unworthy of notice, merely because they cannot, in a period necessary to clear a great capital and insure a fortune, afford the necessary supply of materials. Such situations, according to the present state of the iron business, must remain unexplored. Should, however, a desire for truth once gain footing in the manufactories of iron, and should this natural impulse of the unprejudiced mind keep pace with other branches of intellectual information, we may not despair of seeing many imperfections removed, which were the unavoidable consequence of the period of their creation.

In the application of iron-stone in the blast-furnace, the following particulars ought rigorously to be attended to:

1. Their mixtures, whether clay, lime, or silex: their relative proportions to each other, judging according to the rules formerly laid down; which of them may admit of a diminution of fuel; which of them will afford the quality of iron at the time requisite; and which of them will be most likely, by a judicious arrangement, to give the greatest produce of metal, united with value and œconomy. Iron-stones, united with large portions of silex, have already been stated to require a greater proportion of fuel to carbonate their metal than the other genera. When ballast or forge-pigs are wanted, it stands to reason that siliceous iron-stones ought to be used; not that they contain a greater quantity of iron, but because they form a substitute for the other kinds, which may be more advantageously smelted for the production of more valuable qualities.

2. The quantity of metal which each individual iron-stone may contain, is another object of consideration.

Besides the proportion of mixtures, which chiefly contribute to the fusibility of iron-stones, a second degree of fusibility is dependent upon the richness of the ore in iron: this is so obvious in the use of the Cumberland and Lancashire ores, that the consequences of their introduction will be perceived, by the change of the scoria and metal, in half the time that change would be effected by ordinary iron-stones. It has been frequently noticed, that crude iron contained pure carbon in proportion to its fusibility; then the more fusible, or supercarbonated qualities, must take up, comparatively, a considerable portion of the carbonaceous principle from the fuel. From this results a striking consequence, that the quantity of fuel should, over and above its relation to the mixtures, bear a just proportion to the quantity of iron in the stone: for example, let the weight *per* charge of fuel at a blast-furnace be 400 lb., and let this be supposed sufficiently to fuse and carbonate the iron contained in 360 lb. of iron-stone; let the quantity of metal be supposed 35 *per cent.* then the produce will be 126 lb. Should a change take place, and iron-stone richer in iron be applied, though the same by weight, and should this iron-stone yield of torrefied stone 45 *per cent.* its produce will be 162 lb. or 40 lb. more than the former. As there exists no greater proportion of carbon in the furnace, it is evident that the existing quantity, being distributed over nearly 1-3d of more metal, must therefore be in more sparing quantity in the whole, and the value of the metal consequently reduced.

3. The weight of oxygen contained in iron-stones is the next object of serious consideration. I have already shewn, from experiment, that our iron-stones naturally contain from 9 to 14 *per cent.* of oxygen, which remains after torrefaction: it has also been shewn, that this quantity of hurtful mixture may easily be doubled by over-roasting or under-roasting the stone; and that the bad ef-

fects entailed are in the ratio of its combination with the iron. From a review of the facts adduced on this subject in various parts of my papers, its agency and effects will easily be credited by men of science; its property of constituting the acidifying base of all the acids readily explains the unalienable consequence of its presence with acidifiable bases. The effects are still more pernicious when the oxygen is furnished by the decomposition of water in raw iron-stone; the hydrogen in this case set free, also seizes a portion of the carbon; and these abstractions, united to that produced by the native portion of oxygen in the stone, form an aggregate which frequently reduces the value of iron 40 *per cent.* So long as the princinciples of science are overlooked in the manipulations of the foundry and forge, the existence of such agents will be treated as chimeras of the philosopher and chemist, and the effects hourly produced by them, industriously attributed to causes, which in point of unity or consistency, will not bear the slightest touch of investigation.

Of the Iron produced from the blast furnace. I have already touched upon this in the preceding paragraphs, but the subject is worth pursuing.

" The great object of the manufacturer is, with a given quantity of fuel to obtain as large an amount as possible of highly carburetted cast iron, as this is the kind which bears the highest price in the market: but as from various causes the iron is generally found to be more or less decarburetted, it becomes a matter of considerable importance to ascertain by external characters the principal changes induced by a progressive diminution of carbon, in order that the value of any particular sample may be correctly and expeditiously ascertained. By long and careful observation, it has been found sufficient for all practical

purposes to arrange the several kinds of cast iron under one or other of the four following subspecies.

1. *Smooth faced Iron*, or *No.* 1. of the manufacturers. This seems to be composed of iron supersaturated with carbon, and mixed with a comparatively small proportion of oxyd and earthy impurities. Its upper surface is smooth and convex, entirely free from oxyd, and often covered with a thin crust of plumbago: it presents a coarse granular fracture with a brilliant metallic lustre and a dark blue colour.

2. *Good melting pig Iron*, or *No.* 2. of the manufacturers. This differs from the preceding in containing probably a smaller portion of carbon and a larger admixture of oxyd of iron. Its upper surface is slightly convex and full of small cavities: its fracture is coarse granular towards the centre of the pig, but the concretions manifestly diminish in size as they are situated nearer the surface; its colour is dark grey inclining to blue.

3. *Grey Iron*, or *No.* 3. of the manufacturers. In this the amount of carbon is still further diminished. Its upper surface is level, sometimes slightly concave, and presents more and larger cavities than the preceding, it is slightly oxydated superficially; its fracture is fine granular, and its colour is light grey.

4. *White Iron, forge pigs, ballast Iron.* In this the quantity of combined carbon is smaller and the admixed oxyd larger than in any of the preceding. Its upper surface is concave, rough, and covered with a plate of oxyd; its fracture is compact sometimes tending to striated, its colour is tin-white, occasionally mottled with grey.

We shall now proceed to state in a general way, the circumstances in the smelting which principally influence the quality of the produce. Much depends on the fuel: if the cokes are not perfectly made but retain a part of their bitumen, the whole mass cakes together in the upper

part of the furnace, and instead of descending regularly to the focus of heat, falls down by pieces, and at irregular intervals, so that part of the metal is detained too long before the blast, and in consequence is decarbonized and oxydated, while other portions pass so rapidly through the furnace as never to be thoroughly reduced, hence the amount of the produce is diminished and its quality greatly deteriorated. Nor is it of less importance that the coke should be perfectly dry when put into the furnace, otherwise the water which it contains will be decomposed, the hydrogen and part of the oxygen will dissolve their respective portions of carbon, and escape in a gaseous state, while the remainder of the oxygen will combine with the iron; which will thus be injured, not merely by the privation of carbon, but the positive addition of oxygen. It is further requisite that the proportion of fuel be adapted to the richness of the ore, so that there may be sufficient both to keep up the necessary degree of heat as well as to carbonize the metal: hence as the charges of ore and fuel are always proportioned by measure, if an ore somewhat richer than usual happens accidentally to be employed without a corresponding addition of fuel, the produce, though somewhat increased in quantity, will be more than equivalently reduced in quality. Another circumstance that the manufacturer must carefully attend to, is the proper choice of ore with regard to fusibility, for as it is not only requisite that the iron should be melted, but also highly carbonized, and as coke gives off its carbon with much more difficulty than charcoal does, it is manifest that a very fusible ore would melt long before it arrived at the focus of the furnace, and passing rapidly through, would reach the hearth without having had time to imbibe the proper quantity of carbon. Hence it is that the rich hæmatites, although they afford an excellent quality of iron when smelted with charcoal, produce nothing but white

iron when treated in the coke furnace; while on the other hand argillaceous iron-stone being much more refractory, does not melt till it comes into the very hottest part of the furnace, and therefore has had full time to absorb the desirable quantity of carbon. Another thing to be attended to is the proper regulation of the blast, and this depends upon its dryness, its temperature, its compression, and its direction. The dryness and temperature appear to be principally governed by the season of the year, and therefore are but little capable of being modified by the manufacturer. It is plain that the dryer and colder the air is, the greater will be its effect on the combustion, and it is found by constant experience, that the produce of iron during the summer months is greatly inferior in quantity, and materially so in quality to that which is manufactured in the winter: a clear, dry and severe frost is the most favorable period in every respect for the working of the furnace, and a change to snow or rain is infallibly followed by a corresponding deterioration. The higher the temperature of the blast is when it is delivered into the furnace, the smaller (the degree of compression and other circumstances being equal) will be the quantity of oxygen contained in every cubic foot, and of course the vigour of the combustion. Nor is the force of the blast and its direction a subject of less importance; it is obvious that in proportion as the charge descends, the carbonaceous matter is continually diminishing, hence the proper situation for the focus of the blast is that part of the furnace, where, when the ore shall have arrived, it will be fully carbonized and surrounded with a sufficient quantity of fuel to excite an intense heat, and absorb nearly the whole of the oxygen of the air, and thus prevent it from either oxydating the iron, or carrying off the carbon with which it may be combined. This precise situation, in a furnace properly constructed, will be found to be just within the expansion of

the boshes; but as this is more than four feet above the tuyere hole, the blast must be delivered with great velocity, and in a direction somewhat slanting upwards, in order that it may be reflected by the opposite wall of the crucible, and arrive at its proper place without undergoing any material decomposition. When the blast enters too rapidly, and in too concentrated a state, it renders the line of its passage before it is reflected so cool, that the descending slag which comes within its influence is suddenly solidified, and blown into a tube reaching perhaps half way across the crucible through which the blast continues to rush, and in consequence of this protection, is conveyed with greater precision, and in a less decomposed state into the upper part of the furnace. If after this, the compression of the air is somewhat diminished, the tube still remains firm, often for days together, and the furnace works in the best manner. But on the other hand, when too loose and soft a blast is admitted, and more especially if it be charged with moisture, it is unable to reach the top of the crucible without being decomposed, and the reflection which it undergoes from the wall of the crucible, weakens and disperses it to such degree, that the combustion which ought to take place within the boshes, now occupies the whole upper part of the crucible: in consequence of this, the tube of scoriæ is presently burnt away, the iron almost as fast as it is melted is ignited and oxydized, the tuyere hole glows like the sun, with an intensely vivid white light; the scoriæ from being yellowish white, streaked with blue, becomes green, brown, and finally black, nearly the whole of the iron in the state of oxyd being taken up by it; the blocks of refractory gritstone with which the lower part of the furnace is lined are worn into great holes, and in the space of a few hours prodigious damage is sustained.

The following further remarks on this head are by Mr. Mushet—5 *Phil. Mag.* 128.

When fine (No. 1.) or supercarbonated crude iron is run from the furnace, the stream of metal, as it issues from the fauld, throws off an infinite number of brilliant sparkles of carbon. The surface is covered with a fluid pellicle of carburet of iron, which, as it flows, rears itself up in the most delicate folds; at first the fluid metal appears like a dense, ponderous stream, but, as the collateral moulds become filled, it exhibits a general rapid motion from the surface of the pigs to the centre of many points; millions of the finest undulations move upon each mould, displaying the greatest nicety and rapidity of movement, conjoined with an uncommonly beautiful variegation of colour, which language is inadequate justly to describe. Such metal, in quantity, will remain fluid for twenty minutes after it is run from the furnace, and when cold will have its surface covered with the beautiful carburet of iron, already mentioned, of an uncommonly rich and brilliant appearance. When the surface of the metal is not carburetted, it is smooth like forged iron, and always convex. In this state, iron is too rich for melting without the addition of coarse metal, and is unfit to be used in a cupola furnace for making fine castings, where thinness and a good skin are requisite.

No. 4, or oxygenated crude iron, when issuing from the blast-furnace, throws off from all parts of the fluid surface a vast number of metallic sparks: they arise from a different cause than that exerted in the former instance. The extreme privation of carbon renders the metal subject to the combination of oxygen so soon as it comes into contact with atmospheric air. This truth is evidently manifested by the ejection of small spherules of iron from all parts of the surface: the deflagration does not, however, take place till the globule has been thrown

two or three feet up in the air; it then inflames and separates, with a slight hissing explosion, into a great many minute particles of brilliant fire. When these are collected they prove to be a true oxyd of iron, but so much saturated with oxygen as to possess no magnetic obedience. The surface of oxygenated iron, when running, is covered with waving flakes of an obscure smoky flame, accompanied with a hissing noise; forming a wonderful contrast with the fine rich covering of plumbago in the other state of the metal, occasionally parting and exhibiting the iron in a state of the greatest apparent purity, agitated in numberless minute fibres, from the abundance of the carbon united with the metal.

When iron thus highly oxygenated comes to rest, small specks of oxyd begin to appear floating upon the surface: these increase in size; and when the metal has become solid, the upper surface is found entirely covered with a scale of blue oxyd of various thicknesses, dependent upon the stage of oxygenation or extreme privation of carbon. This oxyd, in common, contains about 15 *per cent.* of oxygen, and is very obedient to the magnet. In place of a dark blue smooth surface, convex and richly carbonated, the metal will exhibit a deep rough concave face, which, when the oxyd is removed, presents a great number of deep pits. This iron in fusion stands less convex than carbonated iron, merely because it is less susceptible of a state of extreme division; and indeed it seems a principle in all metallic fluids, that they are convex in proportion to the quantity of carbon with which they are saturated. This iron flows dead and ponderous, and rarely parts in shades, but at the distance of some inches from each other.

This is a slight sketch of the appearance of the two extreme qualities of crude, or pig-iron, when in a state of fusion. According to the division formerly made, there still

remains two intermediate stages of quality to be described: these are, carbonated and carbo-oxygenated iron; that is, No. 2 and 3 of the manufacturers. Carbonated iron exhibits, like No. 1, a beautiful appearance in the runner and pig. The breakings of the fluid, in general, are less fine; the agitation less delicate; though the division of the fluid is equal, if not beyond that of the other. When the internal ebullition of the metal is greatest, the undulating shades are smallest and most numerous: sometimes they assume the shape of small segments; sometimes fibrated groups; and at other times minute circles, of a mellower colour than the ground of the fluid. The surface of this metal, exposed to external air, when cooling is generally slightly convex, and full of punctures: these, in iron of a weak and fusible nature, are commonly small in the diameter, and of no great depth. In strong metal, the punctures are much wider and deeper. This criterion, however, is not infallible, when pig-iron of different works is taken collectively. At each individual work, however, that iron will be strongest whose honeycombs are largest and deepest.

Carbo-oxygenated, or No. 3, pig iron, runs smoothly, without any great degree of ebullition or disengagement of metallic sparks. The partings upon its surface are longer, and at greater distances from each other than in the former varieties; the shape they assume is either eliptical, circular, or curved. In cooling, this metal acquires a considerable portion of oxyd; the surface is neither markedly convex nor concave; the punctures are less, and frequently vanish altogether. Their absence, however, is no token of a smooth face succeeding; in qualities of crude iron oxygenated beyond this, I have already mentioned that a concave surface is the consequence of the extreme absence of carbon; and that, in proportion as this princi-

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ple is absent, the surface of the iron acquires roughness and asperity.

It may perhaps be proper here to mention, once for all, that although, for convenience, the manufacturer has, from a just estimation of the value of the metal in a subsequent manufacture, affixed certain numbers for determinate qualities of iron, yet it is difficult to say at what degree of saturation of carbon each respective term commences: suffice it then to say, that the two alterative principles, oxygen and carbon, form two distinct classes, that in which oxygen predominates—and that in which carbon predominates; the latter comprehends No. 1 and 2 of the manufacturers, the former includes oxygenated, white and mottled; and the equalization of these mixtures form, as has already been noticed, the variety of carbo-oxygenated crude iron.

I shall now observe some things relative to the various faces which crude iron assumes. No. 1 and 2, with their intermediate qualities, possess surfaces more or less convex, and frequently with thin blisters: this we attribute to the presence of carbon, which being plentifully interspersed betwixt and throughout the particles of the metal, the tendency which the iron has to shrink in cooling is entirely done away; it tends to distend the aggregate of the mass, and to give a round face, by gradually elevating the central parts of the surface, which are always last to lose their fluidity.

Again, that quality of iron known by the name of No. 3, or carbo-oxygenated, or with about half its full dose of carbon, is most commonly found with a flat surface. If we still farther trace the appearance of the surface of pig iron, when run from the furnace, we shall find No. 4 either with a white or mottled fracture, possessed of concave faces, rough and deeply pitted. Beyond this it may be imagined that every degree of further oxygenation would be

productive of a surface deeper in the curve, and rougher, with additional asperities. The contrary is the case: when crude iron is so far debased as to be run from the furnace in clotted lumps highly oxygenated, the surface of the pigs is found to be more convex than that of No. 1. iron; but then the fracture of such metal presents an impure mass covered on both faces with a mixture of oxydated iron, of a blueish colour, nearly metallic. In short, this quality of iron is incapable of receiving such a degree of fluidity as to enable us to judge whether the convexity of its surface is peculiar to its state, or is owing to its want of division as a fluid, whereby the gradual consolidation of the metal is prevented.

These features sufficiently distinguish betwixt the various qualities of crude iron after they are obtained from the blast-furnace: there are, however, criterias not less infallible, whereby we can prejudge the quality of the metal many hours before it is run from the furnace. These are the colour and form of the scoria, the colour of the vitrid crust upon the working bars, and the quantity of carburet which is attached to it. The variety of colour and form in the cinder almost universally indicate the quality of the metal on the hearth. Hence, from a long course of experience, have arisen the following denominations: "Cinder of sulphury iron;" "Cinder of No. 1, No. 2, and No. 3;" and "Cinder of ballast iron." Although at different works, from local circumstances, the same kind of scoria may not indicate precisely the same quality of iron, yet the difference is so small that the following description of the various cinders may convey a very just idea of their general appearance.

When the scoria is of a whitish colour and short form, branching from the notch of the dam, and emitting from its stream beautiful sparks of ignited carbon, resembling those ejected from a crucible of cast steel in fusion, ex-

posed to external air, or to the combustion of fine steel filings in a white flame; if, when issuing from the orifice of the furnace, it is of the purest white colour, possessing no tenacity, but in a state of the greatest fluid division, and, when cold, resembles a mass of heavy torrefied spar, void of the smallest vitrid appearance, hard and durable, it is then certain that the furnace contains *sulphury iron*, i. e. super-carbonated iron. At blast-furnaces, where a great quantity of air is thrown in per minute, super-carbonated crude iron will be obtained with a cinder of a longer form, with a rough flinty fracture towards the outside of the column.

That cinder which indicates the presence of carbonated iron in the hearth of the furnace, forms itself into circular compact streams, which become consolidated and inserted into each other; these are in length from three to nine feet. Their colour, when the iron approaches the first quality, is a beautiful variegation of white and blue enamel, forming a wild profusion of the elements of every known figure; the blues are lighter or darker according to the quantity of the metal and the action of the external air while cooling. When the quality of the pig-iron is sparingly carbonated, the blue colour is less vivid, less delicate; and the external surface rougher, and more sullied with a mixture of colour. The same scoria, when fused in vessels which are allowed to cool gradually, parts with all its variety of light and shade, and becomes of a yellowish colour, sometimes nearly white when the quantity of incorporated metal has been small.

The cinder which is emitted from the blast-furnace when carbo-oxygenated (or No. 3,) iron is produced, assumes a long zig-zag form. The stream is slightly convex in the middle; broad, flat, and obliquely furrowed towards the edges. The end of the stream frequently rears itself into narrow tapered cones, to the height of six

or eight inches: these are generally hollow in the centre, and are easily demolished, owing to their excessive brittleness. The colour of this lava is very various; for the most part it is pale yellow mixed with green. Its tenacity is so great, that if, while fluid, a small iron hook is inserted into it at a certain degree of heat, and then drawn from it with a quick but steady motion, 20 to 30 yards of fine glass thread may be formed with ease. If the colours are vivid and variegated, the thread will possess, upon a minute scale, all the various tints of colouring which is found in the columnar mass. When by accident a quantity of this lava runs back upon the discharging-pipe, it is upon the return of the blast impelled with such velocity as to be blown into minute delicate fibres, smaller than the most ductile wire; at first they float upon the air like wool, and when at rest very much resemble that substance.

The presence of oxygenated crude iron (No. 4,) on the furnace-hearth, is indicated by the lava resolving itself into long streams, sometimes branched, sometimes columnar, extending from the notch to the lowest part of the declivity; here it commonly forms large, flat, hollow cakes, or inclines to form conical figures: these are, however, seldom perfect; for the quantity of fluid lava, conveyed through the centre of the column, accumulates faster than the external sides of the cone are consolidated; and thus, when the structure is only half finished, the small crater vomits forth its superabundant lava, and is demolished. The current of such lava falls heavily from the dam as if surcharged with metal, and emits dark red sparks resembling the agitation of straw embers. Its colour is still more varied than the former descriptions of scoriæ, and is found changing its hues through a great variety of greens shaded with browns. Another variety of scoria, which indicates the same quality of iron, as-

sumes a similar form; but has a black ground colour mixed with browns, or is entirely black. When the latter colour prevails, the texture of the cinder becomes porous; the quantity of iron left, is now very considerable, and such as will be easily extracted in the assay-furnace, with proper fluxes. In cases of total derangement in the furnace, the scoria will still retain this black colour, although the quantity of metal may amount to 25 *per cent:* the fracture, however, becomes dense, and its specific gravity increases in proportion to the quantity of metal it holds incorporated.

The next source of information, as to the quality of the iron in the furnace, is to be got from the colour of the scoria upon the working bars, which are from time to time inserted to keep the furnace free from lumps, and to bring forward the scoria. When super-carbonated crude iron is in the hearth, the vitrid crust upon the bars will be of a black colour and smooth surface, fully covered with large plates and brilliant of plumbago.

As the quality of the metal approaches to No. 2. (carbonated) the carburet upon the scoria decreases both in point of quantity and size.

When carbo-oxygenated iron (No. 3.) is in the furnace, the working bars are always coated with a lighter coloured scoria than when the former varieties exist; a speck of plumbago is now only found here and there, and that of the smallest size. When the quality of the metal is oxygenated (No. 4.) not only have the plates of carburet disappeared, but also the coally colour on the external surface of the scoria; what now attaches to the bars, is nearly of the same nature and colour as the lava emitted at the notch of the dam.

These criteria are infallible; for, as the fusibility or carbonation of the metal is promoted in a direct ratio to the comparative quantity of the coally principle present

in the furnace, so in the same proportion will the vitrid crust encircling the working bars exhibit the presence of that principle in the furnace."

"The highly carburetted, kishy, *smooth faced*, very fusible iron, No. 1, bears the best price, as it is used for all the finer castings, and for cast iron cutting, as forks, scissors, &c.

The iron called *melting iron*, No. 2, is also super-carbonated, or carburetted, but in a less degree; this is used for wheels, beams, pillars, railways, &c.

The *forge pig* is used exclusively for malleable iron.

The following account may serve to throw some light on the faults and defects of iron and therefore I have abridged it from the 8th Sect. of Bergman (or Gadolin's thesis) *de Analysi Ferri.*

Peregrina ferro inhærentia. Of the foreign substances contained in iron.

These are, manganese, arsenic, zinc, plumbago, and sulphuric acid. He might have added, nickel, siderite or phosphat of iron, and copper.

If the ore be fused with 5 times its weight of nitre, the manganese if any, will be discovered by the blue tinge of the fused slag: when iron is also dissolved in the scoria, the glass will be of a bluish green; but I do not know that manganese is any detriment either to iron or steel. Its properties were first detected by Bergman in his dissertation on the white ores of iron. No coal should be permitted to enter the crucible in this experiment. From Bergman's Experiments, most of the Swedish crude iron appears to contain manganese. This substance may also be detected by boiling iron in strong clear vinegar; then add a solution of pearl ash. If there be a *white* precipitate, it is manganese: one part of the dried precipitate, denotes 1-2 a part of metallic manganese. We are sadly in want of a series of experiments to ascertain the effect

of various proportions of manganese and iron fused together. But the opinions of an experienced iron master and a good blacksmith, should be taken upon the specimens produced.

Arsenic, is best detected by roasting the pulverized ore; but Bergman could detect none in the cold-short iron of Grœnge: but he says that its presence, deprives iron of its magnetism, and renders it both red-short, and cold-short. Muriatic acid will take up the iron and leave the arsenic. Aqua regia will take up both, but water will throw down the arsenic.

Zinc is sometimes found in iron, but seldom. The cold-short property is not attributable to this metal. The blue colour of the bright flame, and the white sublimate discover it. But it is not found in cold-short iron.

With respect to plumbago, Bergman was not aware, that a superabundant quantity of charcoal would form it: nor did he then know, I believe, that black lead or plumbago was a very carburetted iron, in which the iron was in small proportion.

With respect to the acid of vitriol, modern knowledge will acquit it of forming any component part of iron, or of being instrumental in any of its faults.

It is singular that in Bergman's Experiments, cold-short iron dissolved in acids, and precipitated by the prussiat of potash into Prussian blue, continued cold-short on being again reduced into metallic iron.

Bergman also attributed the quality of cold-short iron to siderite or phosphat of iron; but I agree with Mr. Mushet that the violent heats of a furnace and refining, are sufficient to decompose this substance.

Nickel has been found in iron, but I know not of any bad effect from it. Nickel precipitated with iron, and the latter reduced to a red or peroxide by hyper-oxymuriate of lime, the nickel may be separated by pure ammonia.

Iron ores frequently contain copper, and if it be in a proportion more than about 12 *per cent.* the iron is manifestly the worse for it. The combination of good copper with good iron does not make it better; and the process of manufacturing malleable iron from the ore, is not sufficient to produce good copper. Where the copper is in large proportion, I know not as yet any method of separating it profitably. Such methods are noticed by Jars and Schlutter, but they are not sufficiently detailed to be relied on.

With respect to the qualities of cold and red short iron, I cannot find any information on which my readers can rely as to the cause. Whether it be owing to an overdose of carbon, to siderite, to arsenic, to manganese, to copper, is not yet settled. The cure can only be found in the refinery furnace, and the tilt hammer, or the rollers.

Of the Refinery or Bloomery, and the conversion of crude iron into malleable iron.

There has been no regular analysis of cast iron, but from the phenomena that take place during its conversion into bar iron, which we shall proceed to describe, it will be sufficiently apparent what are its principal constituent parts.

One of the most obvious differences between cast and bar iron, is the brittleness of the former and the malleability of the latter: this malleability has accordingly been adopted by the manufacturer as the essential character of bar iron, and as affording him a mode by which to judge of the efficacy of the means employed by him in reducing crude to malleable iron.

The first step in the process is refining*. For this purpose the pigs are smelted in a refinery, (the construction of which we have already noticed) by means of char-

* Collier in Manchester, Trans.

coal; and as soon as the metal is in fusion it is let out into a mould of sand to separate the scoria that rise to its surface, and in this state is called a *half bloom*. As soon as it has become solid it is again transferred to the furnace and treated as before. Sometimes even a third fusion is required before the iron shews sufficient malleability to clot into lumps when broken down almost at a fusing heat, by an iron bar. When it has acquired this consistency, it is taken out in moderate size pieces, which being placed under the great forge or *shingling* hammer, are speedily stamped into cakes about an inch in thickness. Several piles of these cakes about a foot high, are then laid on flat circular stones, and placed in the *balling* or reverberatory furnace, where they are strongly heated. As soon as the whole acquires a pasty state, one of the piles is taken out by a workman and drawn under the hammer into a short bar: which being finished, is applied to another of the piles, to which it presently adheres: being then withdrawn, the new portion is welded firmly to the first by means of the hammer, and thus the bar is doubled in length; by repeating the same simple and ingenious operation, the bar is made as long as its weight will conveniently allow. The cracks in the bar are then closed, and its tenacity is improved by heating it afresh in a fire made of coal, called the *chaffery*, (chaufferie Fr.) and again subjecting it to the action of the forge-hammer. It is now in the state of common bar iron, and ought to be entirely free from all earthy particles. After this, according to the use for which it is intended, it is transferred to the slitting mill; where it is laminated and cut up into bars and rods of various dimensions, by which its toughness and compactness is much improved, and is then ready for the smith.

The above method is called *stamping;* but besides this, there is another known by the name of *flourishing*,

which requires a short notice. In this the pigs of cast iron when put into the refinery, are kept for about two hours and a half in a pasty state without actually melting, and at the end of this period the metal is taken out by shovels and laid on the open floor on a plate of cast iron, where it is beaten with hand-hammers in order to knock off the cinders and other adhering impurities. It is afterwards placed under the forge hammer and beaten, at first gently, till the whole mass has acquired some tenacity, and then the middle part is drawn into a bar four feet long, terminated at each extremity by a cubical lump of rough iron: in this state it is called an *Ancony*. It is now taken to the Chaffery, hammered afresh, and the ends being also drawn down to the same dimensions as the other part, the bar is compleated.

A third method of working iron, called *puddling*, was invented by Mr. Cort, (as appears from the specifications of his two patents*) and is we understand coming into general use at Sheffield and other places. It is particularly characterised by combining the reverberatory with the finery furnace, and the whole process is managed in the following manner. The pigs of cast iron produced by the smelting furnace are broken into pieces, and are mixed in such proportions according to their degree of carbonization, that the result of the whole shall be a grey metal. This mixture is then speedily run down in a blast furnace, where it remains a sufficient time to allow the greater part of the scoriæ to rise to the surface. The furnace is now tapped, and the metal runs into moulds of sand, by which it is formed into pigs about half the size of those which are made at the smelting furnace; and these pigs when cold are broken into pieces.

* See Repertory of Arts, III. p. 289 and 361, (old series,) for Mr. Cort's two patents.

A common reverberatory furnace heated by coal, is now charged with about 2¼ cwt. of this half refined grey iron. In a little more than half an hour, the metal will be found to be nearly melted; at this period the flame is turned off, a little water is sprinkled over it, and a workman by introducing an iron bar, or an instrument shaped like a hoe, through a hole in the side of the furnace, begins to stir the half fluid mass and divide it into small pieces. In the course of about fifty minutes from the commencement of the process, the iron will have been reduced by constant stirring to the consistence of small gravel, and will be considerably cooled. The flame is then turned on again, the workman continuing to stir the metal, and in three minutes time the whole mass becomes soft and semifluid, upon which the flame is again turned off. The hottest part of the iron now begins to heave and swell, and emit a deep-blue lambent flame, which appearance is called fermentation: the heaving motion and accompanying flame soon spreads over the whole, and the heat of the metal seems to be rather increased than diminished for the next quarter of an hour; after this period the temperature again falls, the blue flame is less vigorous, and in a little more than a quarter of an hour the metal is cooled to a dull red, and the jets of flame are rare and faint. During the whole of the fermentation, the stirring is continued, by which the iron is at length brought to the consistency of sand, it also approaches nearer to the malleable state, and in consequence adheres less than at first to the tool with which it is stirred. During the next half hour the flame is turned off and on several times, a stronger fermentation takes place, and a loud hissing noise is perceived, the lambent flame also becomes of a clearer and lighter blue; the metal begins to clot and becomes much less fusible and more tenacious than at first; the fermentation then by degrees subsides, the emission of blue flame nearly ceases, the iron

is gathered into lumps and beaten with a heavy-headed tool. Finally, the tools are withdrawn, the apertures through which they were worked are closed, and the flame is turned on in full force for six or eight minutes. The pieces being thus brought to a high welding heat are withdrawn and shingled; after this they are again heated and passed through grooved rollers, by which the scoriæ are separated and the bars thus forcibly compressed acquire a high degree of tenacity.

The more welding and hammering that bar iron is subject to, the tougher it becomes and the more fibrous, or nervous as the French term it, is the fracture. Hence arises the superiority of *Stub iron* to all the other varieties for barrels of fowling pieces and other uses where extreme toughness is required. It is prepared in the following method. A moderately broad ring of the best Swedish iron is placed horizontally and filled with old horseshoe nails (called stubs) set perpendicularly, till it can hold no more: a pointed bar of iron is then driven into the centre of the circle, and thus locks the whole fast together. A welding heat is then applied, and the mass is hammeredvery gently at first, till the nails and ring become compleatly united: it is then drawn down into bars and affords an iron of peculiar closeness, toughness, and malleability."—*Aikin.*

"To produce malleable iron in its pure state, many and various have been the processes adopted: these however have all in some measure fallen short. Malleable iron ought to possess no foreign mixture whatever, to be in a state of purity; but as the modes of operation have hitherto consisted in manufacturing this state of the metal from crude iron, and as crude iron is always found to contain principles inimical to malleability, it is obvious, that the quality of malleable iron will at all times depend upon the degree of expulsion of the alterative mixtures contain-

ed in the crude iron, the destruction of which, and the consequent malleabilization of the iron, constitute the universal acknowledged principles of bar-iron making.

From the imperfect dissipation of oxygen, and carbon in the process of giving malleability, arise the various qualities of malleable iron; these may be arranged in the following order:—1. Hot-short iron;—2. Cold short iron;—and, 3. Iron partaking of none of these evils; and so far it may be denominated pure malleable iron.

1. Hot-short iron is possessed of an extreme degree of fusibility when in contact with a high degree of heat, and is incapable of receiving the weight of a small hammer without dissipating; it is, however, possessed of an extreme degree of softness and ductility when cold, and may then be bent or twisted in almost any direction. Various reasons have been assigned for this destructive property in hot-short iron. I am of opinion, that it arises from the iron containing a small portion of concrete carbon, not extirpated during the operation of rendering the iron malleable; and that in proportion to the quantity of carbon united, so will be the shortness or fusibility of the iron: this variety of iron is always of a dark coloured unmetallic fracture.

2d. Cold-short iron is possessed of the property of withstanding the most violent degree of heat, without exhibiting the least indication to fusion; it remains firm under the heaviest hammer, and is capable, while hot, of being beat into any shape: when cold, however, it is brittle, and possessed of a small degree of tenacity: its fracture is always clear and large-grained, of a light blueish colour. A small portion of iron dissolved in the phosphoric acid is now believed to constitute the cold-short principle of iron. Besides the difficulty of conceiving how an acid could exist in the violent and long continued heats of the refinery, the puddling and balling furnaces, wherein the metal

is subjected to motion, frequently agitated, and extremely divided, how does it happen, that that iron on which the cold-short principle is impressed, becomes more and more cold-short, by a continued exposure to the combination of oxygen with caloric, either excited by blast or the attenuated heat of a wind furnace? This fact would imply a generation of the alterative principle—which is indeed the case—but which cannot be admitted, if the cold-short quality is attributed to the phosphat of iron; unless recourse is had to the supposition of a new combination of this metallic salt during the operation.

If highly oxygenated crude iron, of any manufacture, is exposed to the action of a current of flame, after its small portion of carbon is burnt out, and after the mass has exhibited the proper signs of malleability, it will pass into the state of cold-short iron; and this principle will exist in proportion to the length of the exposure; or, in other words, in proportion to the oxygen presented to the metal, and its tendency to quit the caloric to unite with the iron.

3d. Pure malleable iron derives its strength, tenacity, malleability, and ductility, by being totally deprived of the principles which constitute the cold and hot-short qualities of iron. This is effected in the course of rendering it malleable, either by the attention of the workmen, or from the proper quality of the crude iron used: its fracture is generally clear, consisting of small regular dark blue grains; by much hammering the iron commonly gains fibre, and is then of a light blue colour, uncommonly tenacious when cold. The excellence of pure malleable iron is also manifested by the astonishing degree of heat it withstands without exhibiting the least sign of fusion, or without losing much of its metallic parts by oxydation.

A line of distinction ought to be drawn betwixt the iron produced with wood-charcoal and pit-coal. As the pre-

sent relation of the simple principles of the metal does not immediately interfere with that distinction, it will more properly arrange itself along with the observations on the various modes practised for rendering iron malleable.

However variously conducted the modes of operation are at different works, and in different countries, to produce malleable iron, yet the principle of operation is the same, namely, that by dissipating the carbon and oxygen, contained in the crude iron, bar or malleable iron is the result.

Furnaces of a multiplicity of shapes have been erected for this purpose; but in the most perfect conducted processes hitherto, it has been found, that a heavy loss of metallic parts accompanied the manufacture: 40, 35, to 30 cwt. of crude iron have been used to fabricate 1 ton of finished bars; the quantity used always depending upon its aptness to become malleable, the skillfulness of the workmen, the operation adopted, and the quality of the malleable iron wished to be produced. These observations more immediately relate to the home manufactures of iron with pit-coal; but in many instances they will also apply to those of other countries, where the charcoal of wood is used for fuel.

Since crude iron exists of such a variety of quantities, owing to the various proportions of mixture united with it; and since it is almost universally used to produce bar or malleable iron; it is natural to infer, that there must exist one particular variety of it, which could be appropriated to the manufacture in preference to any other. Theory says that that crude iron, carbo-oxygenated, which contains the alterative principles in equal portions, requires only to be exposed in a fluid state to the action of fire, either in a wind furnace or small blast, By this exposure the carbon becomes volatilized in combination with the oxygen. Practice has however confined the opera-

tion chiefly to the forge pig (oxygenated crude iron). This variety of iron becomes sooner malleable, but is likewise susceptible of early oxydation, and consequently liable to become cold short. Neither can it unite to bar iron those properties from whence are derived great strength and ductility.

When carbonated crude iron is used, the waste then is apt to be excessive: the metal retains for too long a period its fusible principle, which must necessarily expose the mass to a longer continued action of the flame, whereby oxydation on the metal in a fluid state takes place, and a considerable portion of it is destroyed before the iron exhibit signs of infusibility. Malleable iron made from this state of the metal has a great tendency to be red short, and loses also considerably of its weight under the forge hammer.

It has at all times been asserted, that crude iron contains a considerable proportion of its parts, by weight, inimical to malleability; and that, in the operation of refining, it then parts with this proportion of mixture which renders the remainder malleable. A conclusive inference from this would be, that some crude irons contain one half, some three fourths, and others again an equal portion of mixture for iron; seeing these are the proportions lost by iron in the operation of rendering it malleable. The mischief with which this fallacious opinion is fraught is inconceivable; especially as it has been supported by men who have laid claim to scientific and practical abilities; the belief of it slackens the industry of individuals to attempt lessening the loss of real metal; on the contrary, workmen are taught to look upon a large proportion of it as incapable of being metallized, and as only fit for destruction.

If manufacturers of bar-iron would more frequently deprive a given weight of the scoria of the refinery and pud-

ding furnaces, of its iron, they would be more able to estimate the portion of unmetallic parts contained in their crude iron: upon finding the scoria to contain 30, 40, to 50 *per cent.* of iron, equally fit for converting into malleable iron as any part of the original mass, their attention would be more frequently arrested, and employed to devise means, either to prevent the escape of such a considerable proportion of iron, or to fuse such scoria so as to deprive it of the last portion of metal."—*Mushet.*

Conversion of Pig-iron into malleable Iron, and Steel. From Dr. Rees's Cyclopædia, new edition.

1. *Bar, or wrought Iron.* Iron, as obtained by the reduction of its ores in the blast-furnace, contains, as we have before stated, a certain proportion of carbon, which renders the metal unfit for the various purposes of forging, but constitutes its principal value as applicable to the use of the founder. To deprive it of this ingredient certain processes are gone through, the object of which is, by the concurrent action of heat and air, to dissipate the carbon under the form of an elastic compound. The kind of iron chosen for the conversion is that denominated by manufacturers *forge-pig*. It is the lowest quality made for the purposes of art; and, in consequence of its being combined with a smaller dose of carbon than any other, which thus causes it to bear a less price in the market, is doubly preferable for the end required.

The price of *pig-iron* is almost exclusively determined by the quantity of carbon which is in combination with it. The varieties usually distinguished are No 1, otherwise called *grey, smooth-faced*, or *kishy*, metal; Nos 2 and 3, and *forge-pig*. The proportion of carbonaceous matter present in these varieties is differently stated by different experimentalists. Clouet makes the highest proportion to amount to $\frac{1}{4}$th; but from the results obtained

by Mr. Mushet in combining iron *directly* with the doses of charcoal requisite to produce its various sub-carburets, $\frac{1}{11}$th appeared to be the *maximum*. Of this, the following table, published by him in the 13th vol. of the Philosophical Magazine, will afford the necessary proof.

Soft cast steel - - - - - -	$\frac{1}{120}$
Common ditto - - - - - -	$\frac{1}{100}$
Same, but harder - - - - -	$\frac{1}{90}$
Ditto, too hard for drawing - - - -	$\frac{1}{80}$
White cast iron, (same as before called *forge-pig*)	$\frac{1}{31}$
Mottled cast iron (No. 2.) - - - -	$\frac{1}{30}$
Black cast iron (No. 1.) - - - -	$\frac{1}{25}$

The first step in the process of decarbonization, according to the more common mode of operating, is to expose the iron in a furnace, called by some a *refinery*, but by others, to distinguish it from one hereafter to be described, a *run-out furnace*. It consists of a vessel open at the top, imbedded in stone or brick work, about two feet three inches long, two feet wide, and ten inches deep. This is generally, in part, constructed of cast iron; and, when so made, has an outer case about two or three inches distant from the inner one, which is constantly supplied with a stream of cold water to prevent the apparatus from melting. The iron to be decarbonized is placed in this receptacle, and kept in a continual state of fusion for three or four hours by the aid of a coke fire, which is heaped to a considerable height above the level of the vessel, and extended proportionally on the hearth that surrounds it. The size of the hearth is mostly about three yards in length, and from two to three wide, and is completely covered by the funnel of the overhanging chimney. Bellows of considerable size are employed to carry on the process; and the current of air which issues from them is directed immediately on the surface of the iron by one or more *tuyeres*. These *tuyeres* are double, like the case, and con-

tinually cooled by the application of the same means.—When the decarbonization is compleated, the metal is let out at an opening in the side, which has been kept close during the operation by a *stopping* of sand. It flows into a groove about 18 inches wide, and six or seven feet long, constructed of stone in the floor that surrounds the furnace. The bottom of the vessel is so placed as to be nearly on a level with the floor; the only elevation given to it being what is merely sufficient to let the iron run out with facility. A considerable quantity of vitreous oxyd is formed during the process; and the loss in the weight of metal, which is stated to amount to from $\frac{1}{8}$th to $\frac{1}{7}$th, is principally referable to this circumstance. The total quantity of carbon which the iron contains originally, is not estimated at more than $\frac{1}{27}$th; and yet the approach of it to the pure state, or, in technical language, to the state of *bar* or *wrought iron*, after this operation, is very inconsiderable.

The cake of metal procured by these means is broken into lumps of a convenient size, and subjected, in a furnace of another description, to a process known in the art by the name of *puddling*. The furnace, which is also distinguished by the same term, is a variety of the reverberatory; and at the immediate point where the flame strikes upon the hearth, a shallow concavity is worked out, in which the melted iron is exposed. Opposite to it is a door, and through this the metal is kept in continual agitation, by means of a sort of rake, for the purpose of exhibiting fresh surfaces perpetually to the influence of the air. Water is likewise occasionally thrown in, which in some degree contributes to the decarbonization. With the loss of carbon, the iron also loses its fusibility, and about the middle stage of the operation appears in the form of small detached lumps, which scarcely seem to exert any affinity for each other. At length, however, by

much stirring, and frequently pressing them together, they cohere into a pulpy mass; and being gathered into pieces of a convenient size, are carried under rollers, where, after passing through four pairs, in succession, of a gradually diminishing guage, they are produced into plates seven or eight inches wide, and three feet or more in length. Considerable quantities of matter are squeezed out in the rolling, which principally consist of a vitreous kind of oxyd. This is, for the most part, to be referred to the action carried on in the furnace: but some portion of it is, in all probability, created by the combustion of small pieces of fluid metal, which, engaged amongst the particles of the *puddled* mass, are hurled through the air in a state of vivid inflammation, by the compressive violence of the rollers. The total loss thus sustained is estimated at from 1-6th to 1-7th. The plates obtained by this treatment have a very incompact appearance: and if attempted to be worked in the state they are then presented under, would crumble almost wholly into small granulated lumps. To impart to them the necessary closeness and solidity, they are again heated in another kind of furnace, and beaten forcibly with a heavy hammer, which is raised by machinery.

Previously to being thus treated, they are broken up into cakes of small size, and placed upon circular slabs of stone from 8 to 12 inches in diameter. The size of the cakes is in a great measure determined by a particular effect of the last pair of rollers that they are passed through; ribs, of a diamond shape, girding either one or both of them, on the whole extent of their surface, which leave a deep indentation on the plates, so as to render them easily frangible in that direction. The height to which these cakes are piled on the circular slab just spoken of, is generally about 12 inches; and when so prepared, they are placed on the hearth of a reverberatory furnace, which

differs but little in form from that employed for *puddling*, except in being flat at the bottom instead of concave.—The furnace is denominated a *balling furnace;* and the piles of metal *pies* or *balls*. They are continued in this situation until they have arrived at a welding heat, and are then removed by large tongs under the stroke of the hammer. Near to the place a smith's forge is kept in blast, where long bars of iron aro also urged to the welding point; and after the first stroke or two of the hammer, united to the *balled* masses to afford greater convenience in turning them. The masses are beaten out into ingots of about three feet in length; and the bar last mentioned being separated, they are divided deeply by an instrument termed a *set*, to facilitate their being afterwards broken; and the process is then completed. They are in this state called *blooms*, and have yet to undergo another operation, for the purpose of being made into bars or plates. Much loss is sustained by the last treatment, and principally from the same formation of oxyd as was noticed in the preceding case. The quantity thus lost, added to the waste occasioned in the *bloomery*, which comes next to be described, is usually considered as equal to 1-5th of the metal obtained by *puddling;* which will make the total deficiency, by all the operations as nearly equivalent to 35. The ingots or *blooms*, which are received from the hammer, after being broken, over a small wedge-shaped block of iron called a *tup*, are placed in a species of reverberatory, very similar to the *balling furnace*, and denominated a *blooming furnace*, or *bloomery*, They are here heated to welding, and then submitted to the requisite pressure under rollers, which are either plain or grooved, according as the iron is wished to be obtained in plates or in bars. This completes the whole of the processes necessary for making the best malleable iron; and it results from the observations

which have been premised, that, in order to procure one ton of it, five-and-thirty hundred weight of *forge-pig* is previously required.

Two other modes of operating are at present in use; one of which omits the *puddling*, and the other that part of the foregoing process that concerns the fabrication of *blooms*. In the former, iron is exposed to the heat of a charcoal fire, in a species of furnace precisely similar to the one before described as a *refinery*, or *run-out-furnace;* and is continued in that situation, until the metal is thought to be sufficiently decarbonized. It is very frequently stirred during the operation; and when brought *into nature*, (to use the technicle expression) is collected into masses, and removed by tongs under a large hammer, denominated, as applied to this particular use, a *stamping hammer*, where it is beaten into cakes, which are afterwards broken up, and treated in the *balling furnace* as before described. This is the old mode of working, and the iron obtained from it is by many conceived to be of very superior quality. The heat produced is considerably inferior to that afforded by coke in the *run-out furnace*, and the iron is less surrounded by the fuel than in the case just mentioned. The present charcoal fire is properly a *refinery*, and not the one which is used merely as a preliminary to the process of *puddling*. Here the business of decarbonization is at once completed; and the resulting metal is in the same state of purity as that yielded from the rollers, after it has been *puddled* by the other method. *Balling* and *blooming* follow in regular succession, and plates or bars are produced exactly as before.

According to the second mode of treatment in which *blooming* is omitted, the masses obtained from the *balling furnace* are reduced under the hammer into the form of solid; cubical blocks; and when their temperature is too much lowered to be capable of any farther working, they

are again heated in a fire called a *chafery*, which is urged by a powerful pair of bellows, and scarcely differs from a common smith's forge, except in being larger, and the cokes upon it being heaped up to the unusual height of at least two feet. In this situation they are raised to the point of welding, and afterwards hammered out into ingots of a flattened shape. Iron bars are united to them very shortly after they are brought from the *balling furnace*, to afford a greater facility of management, in the same manner as was described in the making of *blooms;* and these, as before, are detached, when the ingot is sufficiently formed. The iron produced in this way is not considered so good as that afforded by either of the other processes, and is employed, for the most part, in the commoner services of art. Repeated rolling, or hammering, is the only means of imparting the fibrous texture so necessary to good bar iron; and as this treatment is less frequent in the present mode of operating, the deficiency of value in the material obtained may very probably be referable almost exclusively to this circumstance.

The above include the whole of the *important* variations that are presented in the manufacture of bar-iron. Other shades of disagreement may be traced in different works; but they are of a nature too trifling and unimportant to merit any particular enumeration. The art is still in its infancy; and the light of chemical science, by being brought to a focus here, cannot fail to disclose many improvements in the present modes of procedure, which will greatly abridge the expense now incident to this valuable branch of national industry. That the mere abstraction of about 4 *per cent.* of carbon should require a sacrifice, in effecting it, of above 40 *per cent.* of iron, appears monstrous beyond example: and as those who are connected with the art become more scientific in their

views, we shall unquestionably find that it will be much more economically accomplished.

When iron has been completely freed from carbon, and has acquired its highest degree of malleability by repeated hammerings, it is by far the most tenacious of all the metals, and is capable of being drawn into the finest wire.

The tenacity of iron, as well as of all the rest of the malleable metals, varies considerably according to its softness. After iron has been kept in a red heat for some time, and suffered gradually to cool, it becomes remarkably changed in point of softness. By being hammered, drawn into wire, or rolled, it increases in hardness to a certain extent; but, at the same time partly loses its malleability. By this mechanical treatment, when cold its strength or tenacity increases; and it may be taken at one point, when it will require a far greater weight to break it, than if it were hammered either more or less.

All the experiments yet published relative to the tenacity of iron, and the other metals, are on this account very defective. The writer of this article has seen an iron wire, when newly annealed, break with a weight of 50 pounds; but, after being drawn through two holes of a wire plate, bear above twice that weight, without sustaining injury. Iron, when properly annealed, will bear more bending backwards and forwards before it breaks, than in any other state: but the strength, or that power which resists a weight, exerted longitudinally to break it, is jointly as the last property and its hardness. Hence the reason why its strength is increased with a certain degree of hammering. The specific gravity of malleable iron, according to Brisson, is 7,788; that of pig-iron being 7,207. Iron, in a state of purity, requires so great a heat for its fusion, that the best crucibles are nearly ready to melt with it. It has however, been fused, and cast into an ingot. It is said to liquify at 158° of Wedgewood. Its

malleability is greatly increased by heat: and by raising it to a very high temperature, it becomes exceedingly soft, and may be brought so near to absolute contact with another piece similarly heated, that they unite firmly together. This process is called *welding*. Its great affinity for oxygen, when heated to a welding point, would very soon reduce it to an oxyd, if it were not for the vitreous matter fusing upon its surface; and it may be still more completely defended, by dipping it in powdered glass or sand."

When pig-iron has undergone either the process of the bloomery, puddling, or refinery, to dissipate the foreign mixtures which the crude iron contained—to reduce or bring to a metalline state, the particles imperfectly metallized in the furnace—and to burn away the superfluous quantity of carbon or charcoal which crude iron always contains in some part or particle of it—the metal becomes less fusible, and is carried under a tilting hammer, to be beaten while red hot: this process, frequently repeated during the period of refining the crude iron into malleable iron, has two principal effects:—1st. It squeezes out and separates, in the form of slag and scoria, all those particles which *have not* been perfectly metallized, and which therefore do not unite with the particles that *have been* perfectly metallized.—2d. It gives to the iron a longitudinal grain, and very greatly increases its tenacity. When it appears to have thus gained the properties of malleable iron, it is beaten into bars, and is ready for market as *Bar-Iron*. The loss of weight in this process obviously depends on the qualities of the pig iron employed.

In this country, tilt hammers are universally used for drawing the iron out of the loops into bars. In England they are almost exploded. The work is done by means of cast iron rollers: for which purpose (I *believe*) the fusible smooth faced pig iron, No. 1, is the best; though the grey cast iron is commonly used. In casting the rollers, the

greater weight they are subjected to, the denser and better they are: for this purpose they are usually cast with a neck of half their weight of superfluous iron, which is afterward cut off, having served as a superincumbent weight to the roller itself, for the purpose of condensing it. They are then turned in a lathe. My friend Mr. P. who was for two years a manager at Mr. John Wilkinson's iron works at Broseley in Shropshire, told me that the experiment of substituting rollers for tilt hammers in the manufacture of bars for nail rods, was made at Broseley somewhere about the year 1790; and that the same power that produced 72 ton of nail rods per week by means of hammers, produced 300 ton when applied to rollers.

Malleable iron thus produced, has the following properties.

It is a metal of a bluish white colour: it is capable of a brilliant polish: it has a styptic taste, when applied to the tongue: it has a perceptible odour when rubbed: its specific gravity varies from 7, 6. to 7, 8, the specific gravity of cast iron being about 7, 2: its specific gravity, its tenacity, and its fibrous texture, are increased by cold hammering, rather than by hammering while hot: it is magnetic: I do not know that any other metal is equally so, (steel excepted,) although symptoms of this property have been observed in nickel, and by Mr. Cavallo in brass. It has been suspected that this magnetic appearance has been owing to some small portion of iron being mixed as an impurity with the metals in question; although the experiments of Bergman and Thenard seem clearly to endow nickel with this property: when iron is well made, and hammered both hot and cold to a proper point (which may be exceeded) a wire of $\frac{78}{100}$ of an inch in diameter will sustain a weight of 549 1-4lb: it may be fused, according to Sir Geo. Mackenzie, at 158° of

Wedgewood's pyrometer.* Iron, and plátina, are the only metals hitherto known that are capable of being *welded*; that is when two pieces of iron are brought to a white heat and placed one upon the other and strongly hammered, they become covered with a kind of metallic varnish, and may be perfectly united: iron when hot strongly attracts the oxygen or pure air of the atmosphere, and puts on a blackish blue appearance as in finery cinder, and smithy slack: these scales can be again changed into malleable iron by being treated with charcoal, which unites with the oxygen and leaves the iron: thin plates of iron may also be blued by heat without exposure to air: when exposed without heat to the air and to moisture, it is changed gradually into rust, which is either iron united to oxygen, or, as I rather believe, to the carbonic acid of the atmosphere, which exists in the atmosphere in greater proportion than is usually suspected. By heating it with charcoal, this rust also can be reduced to malleable iron. At a full red heat, iron is capable of decomposing water, uniting with the oxygen, which forms one component part of water, while hydrogen or inflammable gas which forms the other component part, is set free. The iron in this process is reduced to the bluish black oxyd of iron exactly similar to finery cinder and smithy slack. Mr. Watt, of Birmingham, told me some years ago, that iron at a white heat, would greedily attract and decompose water, if the air in the place were at all moist. These are the principal properties of the metal iron when produced by means of the processes I have detailed.

* The highest point to which I was ever able to raise an air furnace with a fuel of coke, was 172° of Wedgewood, at which heat, grains of crude platina agglutinated but did not melt; I have them still by me in a lump of about an 1 1-2 oz. weight. T. C.

Air Furnace for Cast Iron Founderies.

Fig. 2.

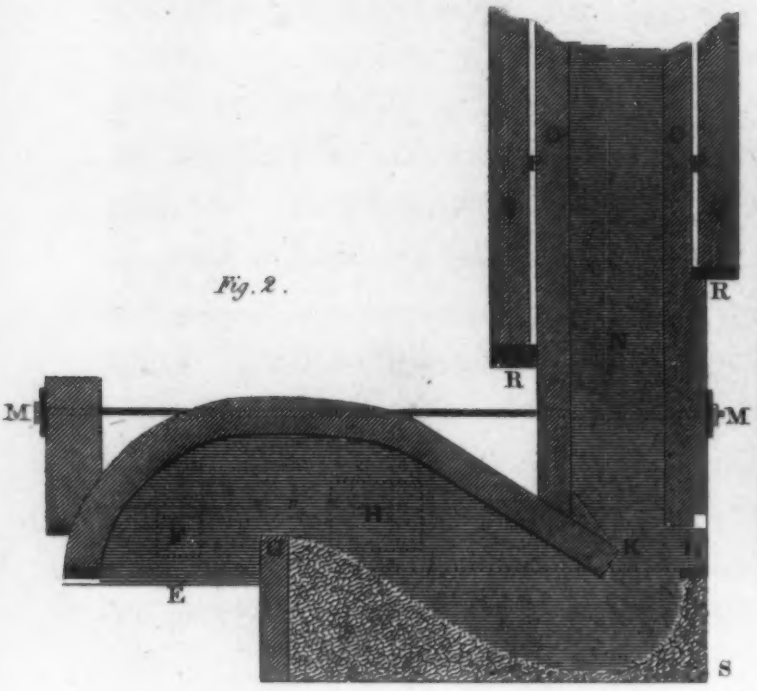


Fig. 3.

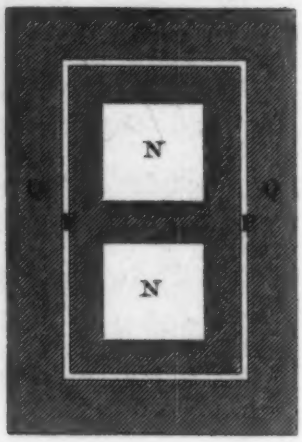
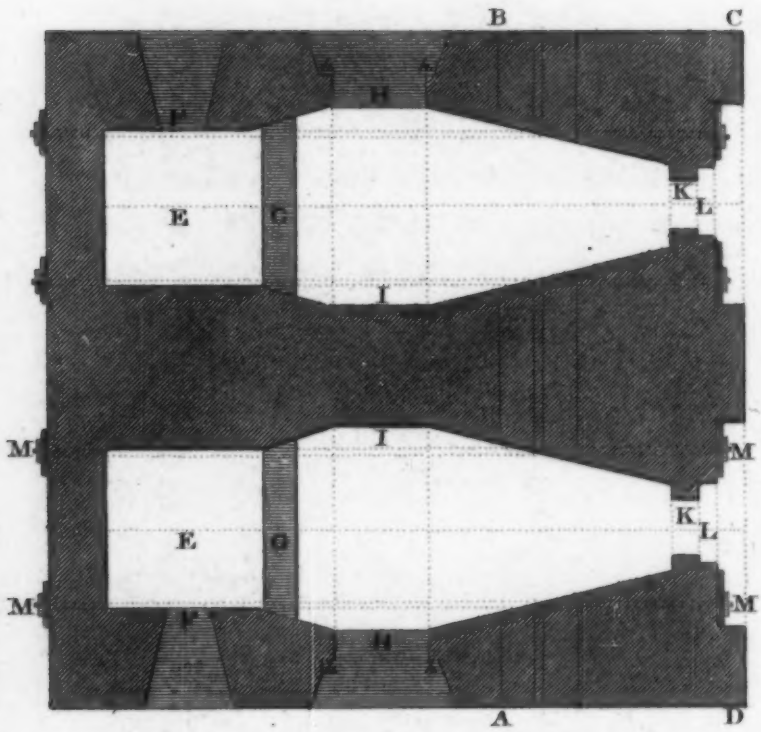


Fig. 1.



C. Tiebout sc.

MISCELLANEOUS ESSAYS RELATING TO IRON.

On the Kind of Air-Furnaces employed in Iron Foundries for casting large pieces of Ordnance, Shafts for Mills, Cylinders, and other heavy Articles. By Mr. DAVID MUSHET, *of the Calder Iron Works.* 15 Ph. Mag.

THE furnaces about to be described are employed for melting pig-iron with the flame of pit-coal. Furnaces of this kind are constructed of various sizes according to circumstances. The small sizes will run down from seven to ten hundred weight, and are used in small foundries for what the trade call *jobbing*.

Fig. 1. (Plate IV.) a ground plan of two large air-furnaces, and chimney for melting pig or cast-iron with the flame of pit-coal.

The letters A B C D point out the exterior dimensions of the stalk or chimney, which is first erected, leaving two openings or arches into which the fore-part of the furnaces are afterwards built. The breadth of the chimney at the particular place which the plan exhibits is 16 feet from A to B, and from A to D or from B to C 6 feet 6 inches. The plan is drawn at that elevation where the flame enters the chimney by the flue or throat, narrowed on purpose to throw back part of the flame, and keep the furnace equally hot throughout, as may be more particularly viewed in the vertical section, fig. 2.

EE, the furnace bars on which the coals rest and where the combustion is maintained.

FF, openings called teasing-holes, by which the coals are introduced to repair the fire.

GG, fire-brick buildings called bridges. These are meant to concentrate the flame, that it may act as violently on the metal as possible. Upon the height of the bridge much depends in fusing the metal speedily, and

with little loss. The height of this may be seen in the vertical section, fig. 2. G.

HH, the charging doors, by which the metal is introduced in the shape and state of pig-iron, lumps, scraps, &c. &c. The iron generally occupies the furnace across to I, called the back wall, and is never meant to approach the bridge nearer than the dotted line, lest the metal in melting should run back into the grates, in place of descending into the general reservoir or cavity below. The corners or notches, *h*, *h*, *h*, *h*, receive a stout cast-iron frame lined with fire-bricks. This is hung by means of a chain and pulley, and can be raised and depressed at pleasure. This frame is, properly speaking, the charging-door, and is always carefully made air-tight by means of moistened sand.

KK, the flues or openings by which the flame enters the chimney. These are 15 inches by 10. On maintaining these openings of a proportionate size to the other parts depend in a great measure the powers and œconomy of the furnace.

LL, lading doors, by which ladles are introduced, in the case of small furnaces, to lift out the metal and distribute it to the various moulds.

MMMM, binding bolts to limit within proper bounds the expansion which takes place in the building when the furnace is highly heated.

Fig. 2. vertical section of one of the furnaces, and its appropriate stalk or chimney.

E, the grates.

F, the teasing-hole.

G, the bridge.

H, the charging door.

K, the flue or opening into the chimney.

L, the lading door.

MM, the binder or binding bolt.

N, the interior of the stalk or chimney, 30 inches square.

O O, the fire brick-work, 9 inches thick.

PP, space of 2 inches for stuffing with sand.

QQ, common brick building.

RR, cast-iron lintels, over which are thrown double 9-inch arches, so that at any time the inferior building can be taken down to make repairs, without shaking or in the least injuring the chimney.

S. The dotted lines here are meant to represent what is called the tapping-hole. When a large piece of goods is to be cast, lifting the metal with ladles would be impracticable. A sharp-pointed bar is driven up this opening. The iron then flows freely out into a large bason of sand made for its reception. It is then conducted, by collateral channels, into the mould.

The space under the curved dotted line from G to L, by S, is filled with a mixture of sand and ashes. When the furnace is prepared to melt, the whole of the bottom receives a stratum of sharp clean sand about two inches thick. This is broken up at night, and fresh sand is substituted for it before the fire is kindled in the morning.

Fig. 3. is a horizontal section of the chimney or stalk, taken where the flues assume a perpendicular direction. The letters in this figure correspond to those in the vertical section, fig. 2. The height of the chimney ought not to be less than 45 feet: if 50 feet, the effect will be sooner and of course better produced.

Remarks upon the Melting of Iron in these Furnaces.

The effect wished to be produced in air furnaces is the fusion of a certain portion of pig or cast-iron for the purpose of being poured or run into moulds to form articles of almost every description.

The preparation previous to melting is as follows:— After the bottom of the furnace is laid, and smoothed with fresh sand, and all the openings made air-tight, the furnace-man introduces a kindling at the teasing-hole, accompanied with new pit-coal. In a few minutes a considerable volume of dark flame mixed with smoke is produced. The fire quickly gathers strength; more coal is introduced; and the furnace now becomes filled with a yellow-coloured flame. By continuing this operation for an hour, or an hour and quarter, the furnace and flame will have become completely white; the latter steady, and at times apparently without motion. The furnace-man now judges the bottom to have been sufficiently hardened for receiving the pig-iron without any risk of sinking. The charging-door is now opened, and the pig-metal thrown carefully and regularly upon that part of the bottom formerly described as being appropriated for its reception. The door is again closed and made air-tight, and the operation of firing continued with unremitting care and attention.

The time of melting depends entirely upon the quantity of metal introduced. The furnaces described above are capable of melting from 50 to 60 hundred weight of metal each, and when there is a moderate circulation of air they will perform this work in 2 1-2 or 3 hours. In half an hour after the metal is introduced it assumes a blackish red colour. It then begins to brighten with every additional fire, and in about one hour appears white, and begins to lose shape, and resemble a wreath of snow.

An eye accustomed to such heats will now discern the metal beginning to drop, and run down the inclined plane in very beautiful streamlets resembling quick silver. Eight or ten of these are visible at a time, and after proceeding half way down begin to form junctions with each other, and flow connected into the general cavity or reservoir. By-and-by this becomes filled, and literally forms

a beautiful molten miror, in which sometimes part of the interior furnace is reflected.

The furnace-man, by searching at the bridge with his fire-iron or teaser, judges when the metal is nearly all gone. Of this he is certain by looking up from the peep-hole of the lading-door. If the streamlets of the running metal have ceased, then the whole is melted, and ready for running out.

In the operation of melting, the three following circumstances ought to be particularly attended to: the thinness or hotness of the metal; the waste or loss sustained in melting; and the quantity of coals employed.

The first is of the utmost importance, as many articles in the foundery business require the metal in a state of the greatest division; otherwise they will be found imperfect when taken from the sand, and unfit for sale. The furnace-man, therefore, is always on the watch to replace the fire as it decays, and keep a large and sharp volume of flame constantly passing over the metal.

The waste or loss of real metal is also an object of great importance. This always bears a relation to the quality of the iron, the strength and cleanness of the coals, and the judgment and attention of the melter. Strong iron is found always more difficult to fuse; this necessarily exposes it for a long period in contact with the flame. The reverse happens with metal that is more fragile, and easier broken in the pig. The length of the exposure in fusing depends on this; and other circumstances being alike, the loss or waste of metal will also be in the same ratio.

There are, however, other facts not unworthy of notice. No. I. pig-iron, or richly carbonated metal, when run from an air-furnace, will be found in point of quality little better than No. II. or carbonated iron. This is owing to a quantity of its carbon being destroyed during the fusion. The loss in melting No. I. iron, therefore, chiefly

consists of carbon; and the deficiency of metal ought never, with a clean bottom, to exceed 1 cwt. in 20.

Carbonated or No. II. iron also becomes deprived of a considerable portion of its carbonaceous mixture in fusion; and when run from the air-furnace is seldom better than No. III. metal. The loss sustained in melting may be averaged at 7 1-2 per cent.

No. III. pig-iron is, after melting in an air-furnace, found whitish or mottled. It is seldom susceptible of the same nice degree of division as the superior qualities, and loses in fusion a much larger proportion of metal, seldom under 10 per cent. and frequently 12 1-2 or 15.

The quantity of coals requisite to melt a given quantity of iron is various, as much depends upon the quality and fusibility of the metal. If the furnace goes one heat a day with No. I. or II. iron, the quantity of coals will be from 20 to 25 cwt. for a ton of iron. If two or three heats a day, or as many tons of iron are melted at one kindling, the proportion of coals will be nearly weight for weight of the iron melted when the coals are mixed with a fair proportion of small: with strong large splint coals, one ton of good pig-iron may be completely reduced with from 12 to 15 cwt. including the previous heating of the furnace.

Facts illustrative of the Shrinkage and Expansion of Cast Iron, &c. &c. By David Mushet, Esq. of the Calder Iron Works. 18 Ph. Mag.

THE high temperature requisite to melt cast iron has prevented the chemical and philosophical world in general from becoming acquainted with many of its habitudes and peculiarities in the different stages of manufacture. Those engaged in foundries are frequently prevented, from the hurry and bustle which attends manufactories.

from making observations, and acquire no habit of detailing them. Others again, from their earliest infancy, have been accustomed to observe, that certain appearances, time out of mind to them, had always followed certain actions performed. They acquire a laconic habit of reasoning; and if asked how such appearances are to be accounted for, their answer is, "They must exist so and so—it is in the very nature of the thing."

It is difficult to conceive a more ample field for observation than an extensive foundry. Combination, change, decomposition, combustion, and deflagration, are constantly performing their respective parts, and continually presenting matter under new and interesting appearances.

Elementary substances, subject to no real change, are modified in a variety of ways by the alternation of heat and cold. The laws which govern these are constantly exerted to produce effects equivalent to the exciting cause; and, while we often remain heedless spectators, these unerring operations are productive of phænomena which frequently elude our sagacity or puzzle our judgment.

The subject of contraction and expansion appears simple, and the presence or absence of caloric alone in the body operated upon frequently explains, in a most satisfactory manner, the whole minutiæ.

But this regards only the heating of certain substances in temperatures short of fusing them. When the object of experiment is exposed to a heat sufficient to fuse it, it then becomes subject to new laws as a fluid, and exhibits phænomena entirely different. By not taking the change of state from that of a solid to afluid into the account, some writers have given an awkward and unsatisfactory account of the laws which regulate iron in these two different states. Before I proceed to detail some experiments made upon this subject, I shall trace out the dif-

ferent states of shrinkage and expansion, as observed in cast iron.

In doing this I shall divide shrinkage into two distinct operations: 1st, Shrinkage, properly so called, when a mass of iron diminishes or skrinks within itself, and would actually displace a smaller quantity of water, and when no degree of heat short of fusion would make it occupy its former bulk or volume. 2d, Contraction, or that diminution of superficial measurement which any body undergoes by evolving its caloric. The surface in this case is never injured; the casting will be found less than the pattern from which it was formed, and simple heating will restore it to its greatest original volume.

The former of these properties cannot exist without the latter, but this last may take effect in full force in many minor operations without any appearance of shrinkage. I only say appearance; for I believe, abstractly speaking, the one never takes place without the other, though in such various minute degrees that it is often difficult to form any estimate of the quantity.

In casting pieces of ordnance we are enabled to judge of the conjoint effects of shrinkage, contraction, and expansion. We shall suppose that a gun mould of any given length is filled with fluid cast iron not subject to these laws; then the size and shape of the gun, when cold, would exactly correspond to the dimensions of the mould, but finding that the piece of casting was considerably altered, that it had shrunk interiorly, was diminished in point of length, and had lessened its diameter, we must seek for a solution of these facts in the explanation of the causes respectively.

First assuming, what shall be hereafter proved by direct experiment, that cast iron occupies less volume when fluid than when solid; that in the act of the arrangement of the moleculæ towards consolidation, it occupies a larger bulk

than at any other period; and that when cold, and in proportion to the absence of heat, so will the volume of the metal be diminished.

1st, Then, *Shrinkage* appears to be dependent upon two causes; the gravitation of the fluid metal, and the expansion of the mould. The latter, I conceive, acts a very powerful part: the immense quantity of caloric combined with the iron is in part easily and almost instantaneously communicated through the sand to the iron box: this creates a disposition to expand, in which it is greatly assisted by the great pressure of fluid iron. That portion of the metal in contact with the interior of the mould is the first to lose its fluidity, and is acted upon and forced to give way in the same ratio of expansion before the subtle and denser fluid. The diameter of the shell of the gun is at this period increased in every part; the fluid iron in the interior descends to occupy the enlarged space, and the head of the gun presents an increasing chasm like the concave of a sand glass. In proportion as the cast iron resolves itself into a solid, a diminution of pressure should take place upon the mould: this would inevitably follow, were not its force replaced by the increased volume of the metal passing into a solid state, which is equivalent to that law which I have termed

2d, *Expansion.* Of the extent of this operation we may judge from the following facts:—All patterns of castings are made somewhat larger than the piece of goods is wished to be: in common cases 1-8th of an inch to the foot is allowed, but in many cases the allowance will be nearly 3-16ths of an inch. In the case of the gun, therefore, the mould would be plus the allowance upon the pattern what space was gained by beating the pattern to loose it from the sand, and all the extra space acquired by the increased volume of the consolidating iron. These, taken collectively, may amount to 1-4th or 5-10ths of an inch;

and so much less will the diameter of the gun be found when cold, to what it would have measured at the climax of its expansion.

3d, *Contraction* immediately takes place of the metal ceasing to expand: to its effects are chargeable the reduction of the increased diameter of the gun, and which seems merely in consequence of the escape of the caloric.

The action or effect of these separate laws will intimately depend upon the quality and fluidity of the metal; with the same quality of iron different effects will be produced according to the division of the fluid, and with the same degree of division in the fluid the extent of the operation of these laws will be different with the different qualities of crude iron. Soft cast iron very hot will shrink and contract less than iron equally hot but of a harder quality, or, which is the same thing, than iron containing less carbon.

In casting cylinders, pipes, and other hollow machinery, the effects of expansion and contraction are manifested without any great degree of shrinkage appearing.

The diameter of the mould in all these castings is generally made from 1-8th to 3-16ths per foot in diameter larger than the casting is wished to be; while the space or vacuity left betwixt the exterior and interior of the mould, called the thickness, is made less than the strength in metal is wished to be.

When the cylinder is cold, however, the diameter, if properly allowed, will be found correct by the operation of contraction in cooling; while the thickness in metal will be found increased, though still correct, by an expansion or separation of the exterior and interior parts of the mould. This last is by the moulder called *straining;* and if great care is not taken to compress the sand firmly round about the mould, the thickness is sometimes increased so much as to render the manufacture unsaleable. Should this

necessary precaution be slightly performed, and the thickness considerably increased, the usual expansion which takes place when the metal passes into the solid state becomes so extensive as to effect a permanent increase of the diameter of the casting, and destroy its use*. The united effects of these two causes force the sand to assume an elevated posture all round the mould, and occasion violent rents and fissures, which become immediately filled with pale blue flame, accompanied by a crackling noise like the snapping of electric matter.

Shrinkage in these castings, particularly if large, would affect the solidity of the vessel by taking place to a considerable extent upon the upper surface, immediately where the runner discharges the metal into the mould. This is in a great measure counteracted by feeding these *gates* or *runners*, after the mould is filled, with several ladles full of fluid iron, and keeping the communication open to the edge of the casting by moving small iron rods up and down in the *gate*. The metal is thus allowed to percolate into the chasm, if any is formed, and prevents any bad consequences likely to ensue from the general shrinkage of the mass.

It is impossible to convey an exact idea of the extent or quantity of shrinkage that takes place in castings, or proportion it to the weight or dimensions of the original mass. The subject of contraction is more within the reach of measurement, and in many cases may be ascertained with great precision.

* The additional thickness always takes place to the exterior of the mould. The pressure can more easily act with effect against the concave than the convex side of the mould. The moulder is fully aware of this in the act of cooling, particularly if the metal has been very hot and of a sharp quality. After he conceives the iron fairly consolidated throughout, he cuts two openings at least in the core or interior part of the mould, and penetrates to the red-hot surface. This gives scope to the contraction of the vessel, and preserves the casting frequently from being destroyed.

The following bomb-shell gauges were cast from very clean wood patterns; the breadth of metal in the hoop was exactly 1·250 inches, and the thickness ·450 inch.

Diameter of Patterns.	Diameter when cast.	Contraction.
1st Pattern 7·500 inches.	7·350 inches.	·150 inch.
2d —— 5·950	5·850	·100
3d —— 5·500	5·430	·070
4th —— 4·550	4·490	·060
5th —— 4·060	4·020	·040

The relative proportion of contraction to the diameters will be as follows:

Contraction of No. I. ·15, equal to 1-50th of the diameter.
II. ·10, —— 1-59½
III. ·07, —— 1-78$\frac{51}{100}$
IV. ·06, —— 1-75$\frac{81}{100}$
V. ·04, —— 1-100$\frac{1}{2}$

It will be seen from this table, that the quantity of contraction is in a due relation to the diameter of the casting. No. IV. seems an exception, however, and appears to have shrunk more in proportion to its diameter than the other four. This may with safety be laid to the score of error in the moulding. In casting flat surfaces, the degree of contraction is in a just proportion to the length of the article.

	Inches.
A front pattern of polished tin measured exactly	24·5
When cast of soft grey iron, and cold, measured	24·250
Contraction	·25

Equal to 1-98th part the length of the pattern; the height of which, or rather breadth, was 20 inches; its thickness a quarter of an inch.

The contraction of two ash-grate patterns was ascertained as follows:

First pattern measured in length -	18·250 inches.
When cast in soft iron - -	18·035
Contraction	·215

Equal to 1-84$\frac{88}{100}$th part the length of the pattern.

Second pattern measured in length	-	11·100 inches.
When cast in soft iron	- -	10·975

Equal to 1-88$\frac{88}{100}$th part the length of the pattern.

The breadth of No. I. was 11 inches, that of No. II. 8$\frac{1}{2}$ inches; the thickness in both was ·475 inch.

I shall now finish this paper with some experiments made upon the casting of cannon shot. This operation is performed by pouring the liquid iron into a mould which is divided into two semi-spheres. The mould is possessed of a joint, which preserves the sphericity of the shot. It is formed by careful turning to gauges made with great care and exactness. This operation exhibits very distinctly the laws of shrinkage, contraction, and expansion; and from it I mean to prove the truth of what I only before assumed: 1st, that cast iron, when fluid, is then more dense than in any other state: 2d, That immediately upon its passing from the fluid to the solid state it acquires its greatest volume; and 3d, That when cold, and always in proportion to the absence of heat, so will be the diminished diameter of the shot.

To prove that cast iron is denser in the fluid state, several pieces of iron may be put into a ladle, and hot fluid iron poured upon them; they will immediately rise to the surface, and expose a considerable portion of their bulk above the surface of the liquid iron. This buoyancy diminishes; and as the pieces of metal approach more and more to the state of fusion that exists in the ladle, they gradually sink till they disappear entirely under the surface; they then rapidly dissolve, and form a part of the fluid iron.

Melted cast iron supports also lead and tin in the same manner; but these soon become dissipated in the great heat of the fluid.

If a 6-pounder shot is placed in the bottom of a 12-pounder mould, or of any size larger, and hot melted metal poured in till the mould is filled, apparently a perfect shot is formed; but a few blows upon the upper part of the sphere, around the gate or runner, detect the surface of the small shot. The thickness of the iron here will not exceed 1-10th of an inch, while the bottom thickness will be nearly a full inch; and if the mould exceeds in diameter that of a 12-pounder, the inequality of thickness is greater. It is evident from this, that six pounds of fluid iron float six pounds of solid iron in the state of a sphere. That this property is permanent, may be further understood from a continuation of the same experiment. If a short allowance of time is made after the mould is filled under the above circumstances, and this dexterously inverted, a fair inclosure will be found, possessing regular and equal thickness of new metal on all sides of the minor ball.

This is easily accounted for upon the same principle. When the mould was full, the ball, as usual, occupied its place near the runner. The iron first run into the mould, meeting with the greatest degree of cold, would immediately consolidate upon the bottom: when the mould was inverted, the ball would naturally tend to elevate itself to what was formerly the bottom of the mould; but its progress would be arrested by that portion of the iron now become a solid, and would remain stationary, more or less central in proportion to the fitness of the moment taken to perform the operation.

That cast iron occupies a greater bulk of volume immediately after it passes into the state of a solid, may be learned from observation as well as direct experiment. If a shot-mould is carefully separated at a certain period after filling, a metallic crust is formed, more or less thick, which is the natural progress of consolidation, but which

is at present an envelope to a considerable portion of fluid contents. In this state the expansion, if any has taken place in the shot and mould, is nearly the same; the former is easily extracted from the under and upper parts of the latter. In about two minutes after, however, the expansion of the shot is more rapid than that of the mould; and at this period is difficult to disengage. As the heat is communicated to the mould, its dimensions enlarge, and the extraction of the shot is attended with less violent efforts. The mould is always filled by the shot till cooling has so far taken place as to reduce the shot-mould to its former diameter. Beyond this, however, the shot still continues to lessen its bulk, so that when cold it will be found to have left its mould by nearly 1-66th part of its diameter. In all cases where shot-moulds are re-filled before they have contracted, by cooling, to their original diameter, their product in shot will be various as to dimensions. The effects of this, particularly in summer, are inconceivable, and though seldom adverted to, will account often for shot being rejected as unserviceable for not passing the gauge. This subject I at one time paid particular attention to, and, to ascertain the fact rigorously made the following experiments:

I selected seven pairs of shot-moulds, well seasoned, of the following sizes, 3, 4, 6, 9, 12, 24, and 32-pounders. These were cast or filled with the same quality of iron three times successively. The first interval of pouring was ten minutes, and the second fifteen minutes.

		Measured. Inches.	Weighed. Lbs.	Grs.
3-pounder shot,	1st Cast	2·724	2	6015
	2d ——	2·730	2	6031
	3d ——	2·736	2	6070
4-pounder shot,	1st ——	3·036	3	6125
	2d ——	3·054	3	6234

	3d	3·087	3	6289
6-pounder shot,	1st	3·240	5	4813
	2d	3·240	5	5031
	3d	3·290	5	5250
9-pounder shot,	1st	4·032	8	5906
	2d	4·050	8	6016
	3d	4·090	8	6236
12-pounder shot,	1st	4·440	11	5250
	2d	4·444	11	5480
	3d	4·512	11	5781
24-pounder shot,	1st	5.556	23	3830
	2d	5·574	23	4485
	3d	5·666	23	5690
32-pounder shot,	1st	6.114	31	5360
	2d	6·156	31	6343
	3d	6.268	32	1530

Upon this table I have only to remark, that the ratio of effect, both in the expansion and increase of weight, is exactly analogous to the weight or diameter of the ball, or, in other words, to the mass of fluid iron poured into the mould. When the last round of pouring was finished, the moulds possessed a temperature respectively to their sizes. The 32-pounder mould was thoroughly red-hot, though nearly two inches in thickness and weighing 140 pounds. In this and in the 24-pounder mould a curious species of adhesion had taken place in the bottom, betwixt the shot and the mould, by the moulders called burning. When the bullet is broken off, the mould exhibits an elevated spongy mass which resists the hardest tempered steel.

About two years after the above experiments were made, I paid particular attention to the effects likely to be produced in a large way in the usual train of manufacture. My observations were conducted in a shop appropriated for shot-casting. The length of the house was 30 feet,

breadth 16, side walls 8 feet, with a pavilion roof of the common range.

The work performed here was the filling of about 150 pairs of moulds, of all sizes, three times each day. These occupied the floor of brick in different ranges, and presented a very large aggregate of heated surface when poured. The quantity of metal thus formed into shot at each cast was nearly a ton. In May 1796 the average temperature of this workshop for several days during casting was 115° Fahr. One day a spirit-of-wine thermometer burst in my hand with a report like a pistol. Its greatest range of scale was 120°: the passages betwixt the moulds, for the movements of the pourers, were 130°. In all these extra temperatures I uniformly observed that a considerable portion of the shot, particularly in the third cast, passed the gauge with difficulty, and many of these found unserviceable for carronades, where the windage allowed upon the calibre of the piece is less. In the middle of August in the same year, during a period of very hot close weather, I made repeated trials, and found the effects always proportioned to the temperature of the workshop. I shall finish this paper with the particulars of one day's observations.

	Temp. of Room.
1st Cast, 9 in the morning - -	65°
in 5 minutes of casting rose to	80
in 10 to	112
in 15 to	128
in 20 to	140
Greatest heat in 35 minutes being three minutes after the pouring had ceased,	156

From 128 to 156° I felt a sensation of cold similar to that when approaching a fire in winter, accompanied by a considerable degree of shivering. About 150° this sensation wore off, and I felt comparatively comfortable. Per-

spiration had now become so violent as to ooze through all parts of my waistcoat, breeches, and stockings. The workmen who carried the metal perspired in such a manner as to wet their large sacking trousers as if they had been soaked in water. The moisture ran in such torrents from their faces and arms, as to be distinctly heard hissing upon the heated moulds. Their step and arms were more agitated than I had ever before observed, and the sinews all over their bodies were uncommonly large, and felt inflated to a great degree. Two men performed the whole labour of pouring; so that each of them in 32 minutes carried half a ton of metal in quantities, in hand-ladles, from forty to fifty pounds each time. The space gone through each time, the return with the empty ladle included, was nearly 120 feet, or fully equal, upon the whole travel, to half an English mile: the half of which space was traversed with a ladle, metal included, weighing 80 pounds. One of the men, immediately after this operation, emptied a pitcher of spring water at one draught which I estimated at five English pints.

The phænomena of the 2d cast were not so marked. So much is the human body the child of habit, that I neither felt the same extent of sensation, nor remarked it upon the workmen, although the thermometer maintained itself for some minutes at 158°. In the afternoon the air began to circulate, and the temperature of the shop became much more moderate. The third cast, however, soon destroyed this pleasant change, and, before half done, the thermometer rose to 164°. Still the workmen seemed to suffer less than in the morning, except on the legs. Most of the ranges of large moulds were throwing off the caloric in ruelle undulations, and exhibiting symptoms of approaching redness. The smallness of the shop admitted only of 2 1-2 feet of passage betwixt range and range; which made the temperature of this spot intolerable.

When the cast was finished I had the doors and windows shut. This made the real state of the moulds visible. The 18, 24, and 32-pounders were all of a dark glowing red heat, and presented an arid and inhospitable glare with which it was impossible long to exist.

Some Account of the Manufacture of Forged Iron Vessels, at Fromont. By M. Ch. Hersart.*

The operations of forging vessels of cast iron may be divided into three distinct parts: 1st, the method of forging the plates; 2d, that of forging the cake or parcel; 3rd, the cold hammering. Of these we shall speak in the order here mentioned, which is likewise the order of fabrication.

To Forge the Plates.—The iron for this manufactory must be very soft and malleable. It has usually the form of bars, ten or twelve feet long; each bar having the form of a long truncated square pyramid. This form is necessary in order to obtain plates of different diameter. The small base is a square of ten lines, or twelfths of an inch, and the greater eighteen lines.

The assistant puts one of these bars in the fire, and when the heated part is ignited, the master forgeman carries it to the small tilting hammer, which is not different from those used in drawing out steel bars. He places the bar on the anvil, not upon one of its faces, but on an edge, as, in this position, the iron is less subject to crack. According to the size of the plate intended to be hammered out, the workman strikes a greater or less portion of the bar, presenting it in all situations to the hammer, in order that the plate may obtain a circular form. Between the plate

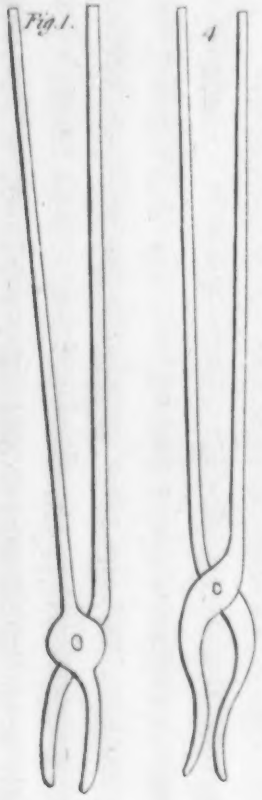
* Journal des Mines, No. 112.

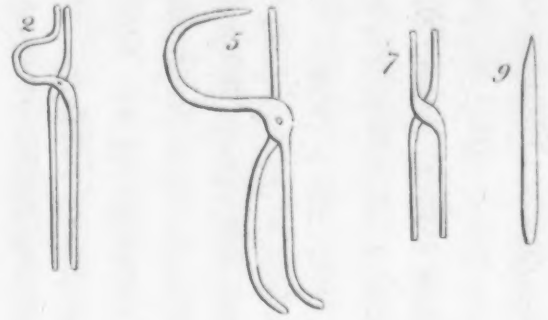
and the bar itself, he fashions a small neck to facilitate its separation. In this manner, the workman continues to forge the plate on both its faces as long as the heat allows, after which he carries the bar to the anvil, and applies a cold chissel to the neck, upon which his assistant strikes in order to separate the plate from the bar. This last is then returned to the fire, in order to continue the operation in making a second plate. Sometimes, but this is only when the plates are small, the workmen make three at once.

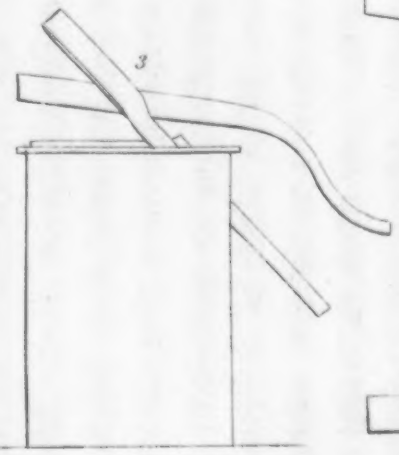
When a sufficient number of plates has been thus fabricated, as they are of different sizes, namely, from three or four inches diameter to a foot, the workman disposes them in parcels, of which each contains four of equal dimensions, and then carries one of them to the hearth of the furnace, where the assistant takes them in the large tongs, Fig. 1, Pl. VI, and puts them into the fire, taking care to change their position often; and when the brass is red hot, the master workman, who holds a small pair of tongs in each hand, carries it under the tilting hammer, after having spread charcoal powder between the plates, to prevent their welding together. The two pair of small tongs have the form of Fig. 2 and are used to give a circular motion to the parcel, and to keep it on the anvil. When he has finished hammering it, he changes the order of the four plates, and in making this change, he is careful to take notice whether any of them have cracked; and where he perceives any crack, he applies the cold chisel, or a wedge to the place on which the assistant gives a blow.

After having changed the situation of the plates in such a manner that the two outside plates become the interior ones, he places this parcel on the hearth, and takes another set, which the assistant has caused to be heated, and he subjects this to the same operation of the hammer. In

Manufactory of forged Iron Vessels.







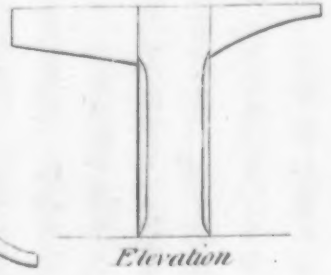
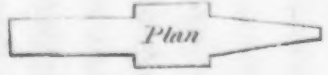


Fig. 6.



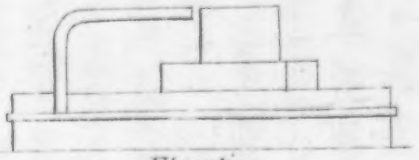
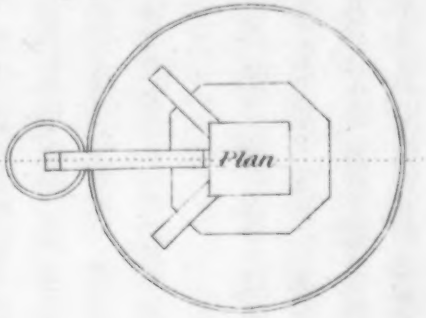
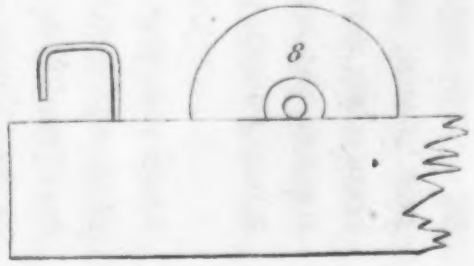


Fig. 10.





this manner the process is conducted until the required dimensions are obtained, namely, after five or six heatings. He then places the plates on the ground to cool; and when cold, he cuts them circularly one at a time, with the large hand-shears, Fig. 3.

This being done, each face of the plate is severally covered with a mixture, formed of the oxide of lead and the oxide of tin, pulverized and mixed with a little water; or, instead of this mixture, clay, diluted in water, may be used, as I have seen practised. Either of these will prevent the plates from welding together, and for that purpose it is that they were applied.

Forging the Cake. The workman takes seven plates of the same size, coated as before described, with the oxide of lead and tin, and he places them upon each other. These seven being placed on two others of larger size, constitute what is called a cake, which is put into the fire by means of large tongs, not differing from the former, except in the mouth, or claws, which are rather higher and curved, as is seen in Fig. 4.

When the cake is red hot, the assistant, who always has the management of the fire, takes it to the edge of the furnace, where the master workman bends the two large plates in one part, and takes up the cake with the tongs already mentioned, Fig. 2. when he carries it to the anvil of the small forge hammer, in order to bend the edge of the two great plates entirely round. The difference between the diameter of the great and small plates, is about two inches; when this is done, he puts the cake again into the fire; and when red hot, he carries it to a smaller caking hammer than that used before, but fixed and moved in the same manner. The anvil is a rectangular parallelopipedon, which rises above the ground not more than one foot; and it has three pieces of iron bended to a right angle, at the height of the angle, which affords three branches

converging towards the anvil, and serving to facilitate the operation of moving the cake during the work next to be described. See the plan and elevation traced, Fig. 10.

The workman being seated before his hammer, takes the cake with two small pair of tongs, and gives it a continual circular motion: during this commencement of the work, he hammers it only on the edge, after which he ignites it, he again carries it to the same hammer, first wetting the edge of the plates to diminish the heat which would only incommode him. By this second forging, he carries his stroke nearer to the centre still continuing the circular motion. By repeating the same operation as far as for eight times, continually approaching the centre, the edge rises every time, and the assemblage of plates become more and more hollow. Accordingly, as this figure encreases, he finds it necessary to change his tongs for others, which differs from the first in the elevation of one of the jaws, and the extremity of the handle, Fig. 5. After seven or eight ignitions, he carries the cake to a kind of anvil, the form of a figure 6, where he holds it with small tongs, Fig. 7, in order to complete the sides, which is done by the workmen hammering in succession; the hammer of the assistant being heavy and double-handed, when this is upon two at once. It is speedily done, and followed by another nearly similar on the bottom of the vessel, by a second hammer, placed near the first, striking on a kind of square anvil. Young girls, afterwards, are employed in scraping the bottom with an iron rod, Fig. 9. One foot and a half in length, terminating at one of its ends in a flattened small termination of steel. After this is done, the workman takes three vessels, one after the other, and presents them under a third hammer, placed near the two first, and moved like them by the same arbor, which carries a small tripping wheel, moved by water. The vessel is placed on the anvil, so that the

hammer, which is pointed at its striking extremity, enters into its cavity. The workman holds the vessel, and shifts its position with his hands and knees. Every stroke of the hammer leaves a slight cavity of the size of a pea, which forms different designs, according to the motion which the workman gives to the vessel. These outlines are not made for the sake of beauty, but to give strength and firmness to the vessel by hammer hardening it. The young girls, afterwards, take the vessels and scrape the interior sides, as was done with the bottom; and lastly, the workmen, on two kinds of anvils, the one plain and circular for the bottom, and the other semi cylindric for the sides, completes their figure with a wooden mallet. Small cracks sometimes appear in the vessel, which the workman close, and the matter is suffered to cool; after which, the cake, which now has the form of a tuencated cone, is carried against a piece of iron bended two ways, Fig. 8, and drove into the wooden block, which supports the gudgeon of the arbor of the hammers. This doubly recurved iron serves to retain the cake which enters under it, and by that means allows the small tongs, Fig. 7, to raise up the edges of the two great plates, which, in part, covered the seven small ones. This being done, the vessels, or hammered pieces, are taken out from within each other. The first is always perforated on account of the immediate purchase of the hammer, and that of the air, which partly converted into scales, fall out by the immediate action of the hammer. As these vessels, when taken out, are more or less bended, the assistant sets them to right by a few strokes of the hammer, after which the master workman cuts their edges with the shears.

Cold Hammering and finishing.—After the vessels are cut round, they are delivered to another workman, who takes them to his separate shop to finish. His first operation is to set the conical surface fair by means of a small

hammer, upon a proper tool. The workman holds the vessel with his right hand with his small tongs, 7; and with his left hand, without tongs, taking care to turn it round continually. Sometimes he performs this operation with a stroke of the hammer; and the complete finish is made by cutting the edges with scissars, similar to those before described.

The furnace made use of is a simple forge furnace, and the fuel is charcoal of fir, excited by wooden bellows.

STEEL.

Preliminary facts and observations.—I have already given some useful notices concerning charcoal. But I think it right again to resume the subject, and to consider it in a point of view more strictly chemical. I do this, in the outset of the consideration of the manufacture of steel, because I consider steel, as PURE IRON, CHEMICALLY UNITED TO PURE CHARCOAL. Pure charcoal, free from earth, ashes, water, oxygen, atmospheric air, or hydrogen, (the substances with which common charcoal even when well burnt, is usually contaminated) is called CARBON by the chemists, and is found naturally in its greatest purity in the diamond; which however Mr. Davy has lately found to contain a very small proportion of earthy matter.

Carbon then is contained in wood; in stone coal; in well burnt charcoal of wood; in well burnt charcoal of pitcoal; in animal substances and the charcoal of animal substances; in the diamond; in plumbago or black lead; in the carbonic acid. The carbonic acid, is united in a solid state to chalk, marble, and limestone; and frequent-

ly also to the ores, calces, and precipitates of many metals; it is found also as the base of the carbonic acid gas which exists in the atmosphere in the proportion of about one part in 100; also in the gas which is produced during the fermentation of vegetable substances; in the air expired from the lungs; in the air evolved from burning fuel; in the choak damp of wells and mines; and perhaps in some other ways, not necessary to be noticed here. In all these substances whether solid or aeriform, the carbon or pure charcoal is one and the same thing.

Carbon united with oxygen in a high degree of heat, becomes carbonic acid gas, the choak damp of mines, which extinguishes flame, and animal life, and exhibits slightly acid properties. The form of air or gas, which the carbonic acid puts on, is owing to its combination with caloric or heat.

The method of ascertaining how much carbon exists in a given substance, is by uniting it with oxygen, (or the pure air which forms 21 parts in 100 of the atmosphere) and then ascertaining the quantity of carbonic acid gas produced; this can be done by means of lime water, which absorbs the carbonic acid gas, and the lime becomes again limestone. For lime is limestone deprived by fire, of water and carbonic acid.

The method of acertaining how much carbon or pure charcoal is contained in iron or in steel, is by dissolving a given weight (100 grains for instance) in oil of vitriol diluted with six times its bulk of water, which will dissolve theiron and leave the carbon or charcoal undissolved in the form of a black powder.

The rough method of making charcoal, is by piling billets of wood on an earthen floor, leaving an opening in the middle of the pile by means of placing the billets slanting toward each other, so as to make the pile nearly a cone with a wide base. Fire is put in at the top of the middle

opening. The pile is covered with earth all round, leaving just vent enough here and there for the fire to spread and to dissipate all the acid of the wood, the water, the oil, the air, &c. but without consuming the substance so as to destroy its bulk or shape: this requires the attention of 3 or 4 days to burn 150 or 200 bushels at a time of charcoal. The lightest woods (generally speaking) make the best charcoal. The charcoal thus burnt, should preserve the shape, and texture, and fibre of the wood. It should be of a deep shining black colour, light, dry, brittle, porous, giving out a ringing sound when struck, and frequently hard enough to strike fire with steel. Hence its powder is used by mathematical instrument-makers, and engravers, to polish their brass and copper; also to polish horn, &c.

This method of making it, is not sufficiently nice and accurate for the purposes of gunpowder. In that manufacture, the wood is distilled in large iron cylinders, to which a tube is adjusted, and the substances distilled over, are detained in close vessels, being chiefly, an acid liquor sold to the callico printers under the name of pyroligneous acid, water, and oily matter. The heat given is very strong; and in this way, all access of common air is prevented. The charcoal is very light, very black, and comparatively very pure, containing nothing but carbon, with a small quantity of ashes and earth.

In the common method of making charcoal, much of it is very imperfectly burnt, still containing moisture, hydrogen, atmospheric air, oily matter, and pyroligneous acid, that is, the acid liquor distilled from green wood by means of heat. The carbon of the wood also becomes oxygenated by decomposing moisture during the process of making charcoal, as well as by imbibing atmospheric air; which it requires a high degree of heat to drive off; the

heat employed in burning wood into charcoal is not sufficient for this purpose.

The best burnt charcoal also, exposed to the air, gains 13 per cent. in weight by imbibing moisture from the air, as well as the air itself.

Hence in a gross way, even good charcoal as it is employed at the furnaces in this country, may be regarded as containing by weight, 15 per cent. water and air of various kinds, oxygen and hydrogen; 15 per cent. earth, ashes, and imperfectly-consumed impurities; and 70 per cent. carbon. The water and atmospheric air would be in greater proportion, if the charcoal were purer; for good charcoal imbibes them with avidity.

From the very accurate experiments of Messrs. Allen and Pepys, which nearly confirm those of Lavoisier and Smithson Tennant, (but not those of Morveau) it appears, that the following woods put into a crucible and covered with perfectly dry sand, exposed for 20 minutes to a red heat, and then for 40 minutes to a white heat, yielded of charcoal as follows:

	Per cent.
Fir-wood (white pine) yielded of charcoal	18·17
Lignum vitæ	17·25
Box	20·25
Beach	15.00
Oak	17·40
Mahogany	15·25

It also appears, that perfectly charred willow wood, weighed while hot, gained 12 1-2 per cent. in weight, on being exposed to the air for 52 hours, and this additional weight proved to be chiefly water.

Also, that in the common atmospheric temperature (60° of Fahrenheit) barometer at 30 inches, 100 grs. of carbonic acid gas may be considered as containing 28·635

grains of pure charcoal, the diamond furnishing but 100 grains of the same gas, from 28·825 grains of diamond.

Also, that at the same temperature, 100 cubic inches of carbonic acid gas, weighs 47·26 grains, and 100 cubic inches of pure air or oxygen gas, weighs 33·82 grains.

By my own repeated experiments I find that good limestone, such as white marble, may be considered as containing 43 per cent. of carbonic acid gas in a concrete state (that is uncombined with the quantity of caloric or heat necessary to render it gaseous or bring it to the state of air.) Hence every 100 parts by weight of good limestone, contains upwards of 12 parts by weight of pure carbon or charcoal, a consideration not commonly or sufficiently noticed. But owing to the size of the lumps in a charge at an iron furnace, and allowing for impurities, I do not think that 100 even of good limestone will yield in the usual heat of the furnace more than from 35 to 38 of carbonic acid gas, containing about 11 per cent. of pure charcoal. I would further observe, that where the slag is an uniform dense glass, without blebs, all the limestone is deprived of its carbonic acid, for though oxygen or the base of pure air, *will* unite to glass, carbonic acid *will not*. *Pure* limestone precipitated from a solution in acids by a solution of pearl-ash, contains nearly 44 grains of carbonic acid in the hundred.*

From the same experiments of Messrs. Allen and Pepys it appears, that 100 grains of carbonic acid gas

* To try your limestone: Take 100 grains in powder, dissolve it in a mixture of 1-2 spirit of salt and 1-2 water. Wash with a pint of hot water what remains undissolved, and dry it for an hour in the heat of boiling water. Weigh it, and it gives the weight of the impurities. This method may be checked, by throwing down the limestone by means of a solution of pearl ash, wash and dry it: weigh it: the weight added to the impurities ought to make up 100 grains.

were produced from the combustion of 28,235 grains of welch coal, which is a graphite or anthracite coal, burning with little or no flame or smoak, and similar to the Lehigh and Wilkesbarre coal of Pennsylvania, or the Kilkenny coal of Ireland. Also that 28,46 grains of plumbago or black lead produce 100 grains of carbonic acid gas; the additional weight in these cases arising from the oxygen employed in the combustion, and united to the carbon. Also that pure well burnt charcoal of wood, made in a white heat in a close vessel, and weighed while it is still quite hot, consumes as much oxygen to convert it into carbonic acid, as the diamond does within $\frac{1}{100}$ of a grain in 100 grains. Hence, that whatever imperfectly made charcoal may be, pure, well-burnt charcoal made as above, is not an oxyd of carbon, and contains no hydrogen.*

By the experiments of these gentlemen, 100 parts of animal charcoal carefully made from muscular flesh does not contain more than 67,5 of carbon and produces 23,72 *per cent.* by weight of carbonic acid gas, but I suspect ani-

* The following brief notice of the use of charcoal may be crouded into a note.

It is the best tooth powder known when used fresh. It takes away the smell of putrid meat. Three times I have boiled legs of mutton, offensive to the scent, in hot water containing a shovel full of live coals taken from the bottom of the (wood) fire: when boiled for 10 minutes, the meat taken out, and wiped, the stinking water thrown away, and the boiling repeated in the same manner; the mutton became eatable. It takes away the peculiar flavour of bad spirits. Charred casks keep water a long time fresh. Meat suspected as liable to become putrid, is better kept in charcoal than in any other way. It is an excellent non-conductor of heat, and therefore should be used for lining the outside of vessels, wherein ice or cool liquors are required to be kept. Animal charcoal, as of bones (fresh made ivory black) peculiarly answers, for clearing and fining vinegar.

mal charcoal is decomposed by a less heat than charcoal of pine or oak; a consideration that I regard as of great importance in this country, both as to the facility of making steel, and the economy of wood. From some experiments of Vauquelin, steel seems to contain phosphorus; if so, it was probably made by animal charcoal; which is always preferred for case-hardening.

That steel, whether cemented steel, or cast steel, is merely charcoal combined with iron, will appear from the various processes of making it. But the fact can be proved by direct experiment. Take 100 grains of filings of pure malleable iron; as much of cemented or blistered steel; as much of cast steel. Dissolve each of these separately in spirit of salt and water, half and half, in a warm place. The solution of the iron will furnish no black powder remaining undissolved; the two other solutions will; and the cast steel the most. Pure charcoal is not capable of being dissolved in any acid.* Indeed the common mode

* The following facts relating to the indestructibility of charcoal, are well worth attending to. "The beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city, and during the lapse of between 17 and 1800 years, the charcoal remains as entire as if it was made but yesterday, and will probably continue so to the end of the world. The incorruptibility of charcoal was known in the most antient times. The famous temple of Ephesus, was built upon wooden piles which had been charred on the outside to preserve them. 3 Watson's essays 48.

"It is said there still exists charcoal made of grain in the time of Cæsar, which is in so compleat a state, that the wheat may be distinguished from the rye. Willich.

"About 40 years ago, a quantity of oak stakes were found in the bed of the Thames in the very spot where Tacitus, says that the Britons fixed a vast number of such stakes to prevent the passage of Julius Cæsar and his army. They were charred to a considerable depth, retained their form compleatly, and were firm at the heart. Dr. Robison.

of trying whether a piece of metal be steel or not is a proof of this. Clean the surface; put on it one drop of common aqua fortis; let it remain a minute; wash it (without rubbing it) in water; if it be iron the spot will be white; if it be steel the spot will be black, from the undissolved carbon.

If then steel be a composition of iron and carbon, can it be made by means of any thing that contains carbon? It can.

1st. The common method of making steel is by cementing iron bars with charcoal, and applying a strong heat.

2dly. The French chemists say that they have made it at once from malleable iron, by means of limestone and bottle glass. English cast steel is made as I have been told, by melting blistered steel with powdered limestone mixed with powdered glass.

3dly. I have seen at Birmingham steel made by passing steam into a furnace in which iron was in a state of fusion; the steam being decomposed by the charcoal, furnished carbonic acid gas which in its turn was decomposed by the iron. But this process did not answer in a large way, either in point of economy, or uniformity of product.

4thly. Steel has been made, by mixing a small quantity, of diamond powder with malleable iron; this experiment has been repeated both in France and England.

5thly. It has been made by mixing black lead with malleable iron, and exposing the mixture to a melting heat.

6thly. By mixing one-fifth part of kishy, supercarbonated smooth faced crude iron, with common malleable iron.

7thly. It can be made with the charcoal of hoofs, horns, woollen, bones, or any other animal substance: and as

The writings of the antients were with atramentum made of glue and lamp-black, or powdered charcoal, and they are now perfectly black. See Parke's Ch. Catech. 267.

these give out their carbon with a less degree of heat than the hard charcoals of wood, they are sometimes used in the steel furnaces of Pennsylvania, where the only reasons why steel is not made as good as in England, are, 1st, the want of heat sufficient from a wood fire; 2dly, the use of iron not sufficiently pure in quality, or well hammered in the bar; 3dly, the use of charcoal, too hard, not sufficiently burnt, and not used fresh.

These facts and observations well considered, will throw light upon the common processes for making steel, which I am about to detail.

Steel is made in 3 ways,

1st. It is made in Sweden and Germany from the crude iron. It cannot (as is said) be thus made from iron smelted with the coke of pitcoal. When the iron is carried in small pigs to the bloomery or refinery, it is melted on the hearth under charcoal. Grey cast iron is commonly used for the purpose. If it be much stirred and exposed to the blast in the bloomery, the superfluous carbon or charcoal will be burnt away; and by frequent heating and hammering it will become malleable bar iron: but if instead of being frequently stirred, the slag only is raked off as it forms, and the loop covered with charcoal, it will be a coarse kind of steel, much used on the continent of Europe for rough work, and cheap tools.

In order to obtain *Iron*, the fire place must be larger than for steel, and the tuyer must be inclined so as to direct the blast to the surface of the iron; the heat must be given gradually, and the iron frequently stirred, and raked, and kept in the state of a paste. But to make *Steel*, the heat must be given more suddenly, the iron must be placed on a bed of charcoal dust, and become fused, so as to sink below the Scoriæ or slag, and if these are removed, their place must be supplied by charcoal. In making iron at the refinery, the charcoal is burnt away; in making steel,

a more perfect union is produced between the charcoal and the iron. The process as described by Hazenfratz is as follows:

"The crude iron is reduced into thin plates, or leaves, when it is drawn from the smelting furnace. For this purpose a mould, or hemispherical cavity, is prepared before the furnace. It is formed of the scoriæ reduced into very fine powder, and wetted to make them adhere together.

The work is then opened with an iron bar, in order that the scoriæ may flow into the mould, and dissipate its moisture. These are in the next place taken out, and the metal itself is suffered to flow at first in a small stream, and afterwards more speedily. The aperture is enlarged in proportion as it flows out, and at last the scoriæ fall on the iron, and cover it in the mould. The furnace is then again closed, and the blast renewed. Water being thrown on the scoriæ which occupy the upper portion of the mould, they become fixed, and in this state are removed. A second portion of water is then thrown on the naked surface of the metal, which congeals to a small depth. The thin congealed plate is taken off, and a second aspersion of water is made, which affords a third plate. In this manner the process is continued, until as much of the metal is converted into plates as can be effected during the fluidity of the mass.

At some works the iron is melted in a particular furnace from the pig, for this purpose; but this second operation is evidently wasteful both of time and fuel.

The plates are intended to be made into either iron or steel.

In the process for making bar iron, the first operation consists in roasting the plates on a hearth, upon which they are arranged; a passage being formed with bricks, in order that the wind of the bellows may be directed from one extremity to the other. They are then covered with char-

coal, and urged strongly with the bellows. The plates by this roasting, which destroys the charcoal of the cast iron, begin to assume the qualities of bar iron, after which they are carried to the fincry furnace. The body of this furnace is more capacious than that which is intended for steel. The iron is covered with charcoal and scoriæ, and the tuyere is inclined so that the blast strikes on the plates of metal. When the fusion is complete, the scoriæ are let out, the mass is frequently turned to expose it to the blast, and, lastly, the process being completed, the iron is conveyed to the hammer.

If the object be to form Steel, the furnace made use of is more contracted and deep. It is lined with pulverized charcoal, moistened and rendered solid by beating. The plates are disposed therein, and covered with scoriæ and charcoal. The position of the tuyere is nearly horizontal, in order that the stream of air may strike the fuel, and not the metal. When the metal begins to assume the solid state, the coal is taken off, the scoriæ are suffered to flow out, and scales and fragments of steel are driven by hammering into the soft mass.

The piece is afterwards melted a second time with the same precautions as before; and when the metal is thought to be sufficiently refined, the scoriæ are drawn off, and the mass is conveyed to the hammer to divide it into several pieces, which are to be separately forged out.

We see that all these operations are directed to the means of destroying the charcoal of the crude iron, when bar iron is wanted; but when steel is required to be made, the metal is not only preserved from the contact of the air, but the vessel is lined with charcoal, in order that, by its contact with the fused matter, it may supply any portion of that principle which may be wanting.

In the foregoing process there are two fusions of the metal. In the latter it is not only completed by the se-

cond fusion, but it is rendered more homogeneous. This method is excellent, and is perhaps the only means by which an exceedingly good steel can be had.

The other part of the process is worthy of much attention, namely, the reduction of the crude iron into plates. When bar iron is wanted, these plates roast with more facility on account of the great surface they present to the air. And when steel is wanted, they are more readily fused, and sink beneath the scoriæ, which prevents the charcoal of the iron from being consumed by the action of the air. On the contrary, they absorb what might have been wanting from the lining of the hearth or cavity, which is prepared in such a manner, as to support itself without being consumed, through the whole of the operation.

When the steel has congealed in the furnace, it is taken out and divided into several portions more or less considerable, which are carried to the hammer. Here a separation is made of such portions as are not reduced into steel, but iron, and which occupy the surface of the pieces. Each piece is drawn out into bars, which are reduced into other smaller bars of different dimensions, by separating the softest parts from those which are more hard.

For steel of a superior quality, several bars of the soft and hard kinds are united by welding and forging. The hardest are placed in the middle.

We have shown that in order to obtain steel from crude iron, it is necessary to have an iron abounding with coal; but there is an excess which is hurtful. The black crude iron, which contains too much coal, affords a steel so brittle as to be of no use. This kind of steel becomes fixed with more difficulty than good steel. When the workman perceives this symptom, he may prevent the bad effect by adding a certain quantity of old iron fragments, which deprives the too steely metal of its excess of coal, and, by incorporating with it, produces an uniform mass

of good steel. When the crude iron is of such a nature as to afford, brittle steel, it is usual to mix in the refining furnace a quantity of another kind of crude iron, which may modify its quality.

Though iron and steel are distinguishable by very striking qualities, there is, nevertheless, a point of contact at which they are confounded: the softest steel may be considered as a very hard iron, and, in fact, the several kinds of iron differ in hardness by the same principle which constitutes steel. They all retain a small portion of charcoal, which escapes the operation of refining. Those which contain the least are under like circumstances more flexible, soft, ductile, and susceptible of acquiring by the action of the hammer that fibrous form which constitutes what is called the grain of iron. Hence it is that different kinds of bar iron are sometimes obtained from the same crude iron, though the operation is apparently the same. It is sufficient for this effect that the inclination of the tuyer be changed. 2 Nich. Jour. qto. p. 66.

The next kind of steel, is 2dly, *Steel of cementation*; blistered steel.

Observations on Iron and Steel. By Joseph Collier. From the Transactions of the Manchester Society—with notes by T. C.

AFTER examining the works of different authors who have written on the subject of making iron and steel, I am persuaded that the accounts given by them of the necessary processes and operations are extremely imperfect. Chemists have examined and described the various compound minerals containing iron with great accuracy, but have been less attentive to their reduction. This observation more particularly applies to steel, of the making of which I have not seen any correct account. It is sin-

gular to observe how very imperfectly the cementation of iron has been described by men of great eminence in the science of chemistry. Fourcroy states the length of time necessary for the cementation of iron to be about twelve hours; but it is difficult to discover whether he alludes to cast or to bar steel: for he says, that short bars of iron are to be put into an earthen box with a cement, and closed up. Now steel is made from bars of iron of the usual length and thickness: but cast steel is made according to the process described by Fourcroy, with this essential difference—the operation is begun upon bar steel, and not bar iron.

Mr. Nicholson is equally unfortunate in the account given in his Chemical Dictionary. He says, that the usual time required for the cementation of iron is from 6 to 10 hours, and cautions us against continuing the cementation too long; whereas the operation, from the beginning to the end, requires 16 days at least. In other parts of the operation he is equally defective, confounding the making of bar with that of cast steel, and not fully describing either. In speaking of the uses of steel, or rather of what constitutes its superiority, Mr. Nicholson is also deficient. He observes that "its most useful and advantageous property is that of becoming extremely hard when plunged into water." He has here forgotten every thing respecting the temper and tempering of steel instruments, of which, however, he takes some notice in the same page. "Plunging into water" requires a little explanation: for if very hot steel be immersed in cold water without great caution, it will crack, nay sometimes break to pieces. It is however necessary to be done, in order to prevent the steel from growing soft, and returning to the state of malleable iron; for, were it permitted to cool in the open air, the carbon which it holds in com-

bination would be dissipated*. I shall at present confine my remarks to the operations performed on iron in Sheffield and its neighbourhood, from whence various communications have been transmitted to me by resident friends, and where I have myself seen the operations repeatedly performed. The iron made in that part of Yorkshire is procured from ores found in the neighbourhood, which are of the argillaceous kind, but intermixed with a large proportion of foreign matter. These, however, are frequently combined with richer ores from Cumberland and other places. The ore is first roasted with cinders for three days in the open air, in order to expel the sulphureous or arsenical parts, and afterwards taken to the furnaces, some of which are constructed so that their internal cavity has the form of two four-sided pyramids† joined base to base; but those most commonly used are of a conical form, from forty to fifty feet high. The furnace being previously heated in various proportions according to the nature of the ore, is charged at the top with coal-cinder and limestone. The limestone acts as a flux, at the same time that it supplies a sufficient quantity of earthy matter, to be converted into scoriæ, which are necessary to defend the reduced metal from calcination, when it comes near the lower part of the furnace. The fire is lighted at the bottom; and the heat is excited by means of two pair of large bellows‡ blowing alternately. The quantity of air generally thrown into the furnace is from 1000 to 1200 square feet in a minute.¶ The air passes through a pipe, the diameter of which is from two inches

* It is the opinion of some metallurgists, that a partial abstraction of oxygen takes place, by plunging hot metal into cold water.

† Rather two inverted cones, of which the base of the larger rests upon the base of the smaller.

‡ These are now discarded and large cast iron cylinders substituted in their stead.

¶ From 1500 to 1800 out of a pipe of 2¼ or 3 inch bore.

and a quarter to two and three quarters wide. The compression of air which is necessary is equal to a column of water four feet and a half high.* The ore melts as it passes through the fire, and is collected at the bottom, where it is maintained in a liquid state. The slag, which falls down with the fused metal, is let off by means of an opening in the side of the furnace, at the discretion of the workmen. When a sufficient quantity of regulus, or imperfectly reduced metal, is accumulated at the bottom of the furnace (which usually happens every eight hours,) it is let off into moulds, to form it for the purposes intended, such as cannon or pig iron.—Crude iron is distinguished into white, black,† and grey. The white is the least reduced, and more brittle than the other two; the black is that with which a large quantity of fuel has been used; and the grey is that which has been reduced with a sufficient quantity of fuel, of which it contains a part in solution. The operation of refining crude iron consists in burning the combustible matter which it holds in solution; at the same time that the remaining iron is more perfectly reduced, and acquires a fibrous texture. For this purpose, the pigs of cast iron are taken to the forge, where they are first put into what is called the refinery; which is an open charcoal fire, urged by a pair of bellows, worked by water or a steam-engine; but the compression of air in the refinery ought to be less than that in the blast-furnace. After the metal is melted, it is let out of the fire by the workmen to discharge the scoriæ, and then returned and subjected to the blast as before. This operation is sometimes repeated two or three times before any appearance of malleability (or what the workmen call coming into nature) takes place; this they know by the metal's first assuming a granular appearance, the particles appearing to repel each other, or

* This ought to be 6 inches of mercury, or 6 feet of water.

† Mottled.

at least to have no signs of attraction. Soon afterwards they begin to adhere, the attraction increases very rapidly, and it is with great difficulty that the whole is prevented from running into one mass, which it is desirable to avoid, it being more convenient to stamp small pieces into thin cakes: this is done by putting the iron immediately under the forge hammer, and beating it into pieces about an inch thick, which easily break from the rest during the operation. These small pieces are then collected and piled to the height of about ten inches upon circular stones, which are an inch thick and nine inches in diameter. They are afterwards put into a furnace, in which the fire is reverberated upon them until they are in a semi-fluid state. The workmen then take one out of the furnace, and draw it into a bar under the hammer; which being finished, they apply the bar to another of the piles of semi-fluid metal, to which it quickly cements, is taken again to the hammer, the bar first drawn serving as a handle, and drawn down as before. The imperfections in the bars are remedied by putting them into another fire called the chafery, and again subjecting them to the action of the forge-hammer.

The above method is now most in use, and is called *flourishing;* but the iron made by this process is in no respect superior to that which I am going to describe. It is however not so expensive, and requires less labour.

The process for refining crude iron, which was most common previous to the introduction of flourishing, is as follows:

The pigs of cast iron are put into the refinery, as above, where they remain until they have acquired a consistence resembling paste, which happens in about two hours and a half. The iron is then taken out of the refinery, and laid upon a cast iron plate on the floor, and beaten by the workmen with hand-hammers, to knock off the cinders and other extraneous matters which adhere to the metal. It is

afterwards taken to the forge-hammer, and beaten first gently, till it has obtained a little tenacity; then the middle part of the piece is drawn into a bar about half an inch thick, three inches broad, and four feet long, leaving at each end a thick square lump of imperfect iron. In this form it is called Ancony. It is now taken to the fire called the chafery, made of common coal; after which the two ends are drawn out into the form of the middle, and the operation is finished.

There is also a third method of rendering crude iron malleable, which, I think, promises to be abundantly more advantageous than either of the two former, as it will dispense both with the refinery and chafery; and nothing more will be necessary than a reverberating furnace, and a furnace to give the metal a malleable heat, about the middle of the operation. The large forge-hammer will also fall into disrepute, but in its place must be substituted metal rollers of different capacities, which like the forge-hammer, must be worked either by a water-wheel or a steam-engine.

It is by the operation of the forge-hammer or metal rollers, that the iron is deprived of the remaining portion of impurity, and acquires a fibrous texture.

The iron made by the three foregoing processes is equally valuable, for by any of them the metal is rendered pure; but after those different operations are finished, it is the opinion of many of the most judicious workers in iron, that laying it in a damp place for some time improves its quality; and to this alone some attribute the superiority of foreign iron, more time elapsing between making and using the metal. To the latter part of this opinion I can by no means accede, as it is well known that the Swedish* ores contain much less hetero-

* Steel is commonly made of Swedish iron. Oregrund iron as it is called, but that is only the mart: the ore is from Dannemora.

geneous matter than ours, and are generally much richer, as they usually yield about 70 *per quintal* of pure iron, whereas the average of ours is not more than 30 or 40* : add to this, that the Swedish ores are smelted in wood fires, which gives the iron an additional superiority.

Iron instruments are case-hardened by heating them in a cinder or charcoal fire; but if the first be used, a quantity of old leather or bones must be burnt in the fire, to supply the metal with carbon. The fire must be urged by a pair of bellows to a sufficient degree of heat, and the whole operation is usually completed in an hour.

The process for case-hardening iron is in fact the same as for converting iron into steel, but not continued so long, as the surface only of the article is to be impregnated with carbon. Some attempts have been made to give cast-iron, by case-hardening, the texture and ductility of steel; but they have not been very successful. Table and pen-knife blades have been made of it; and, when ground, have had a pretty good appearance; but the edges are not firm, and they soon loose their polish. Common table knives are frequently made of this metal. The cementation of iron converts it into steel, a substance intermediate between crude and malleable iron.

The furnaces for making steel are conical buildings; about the middle of which are two troughs of brick or fire-stone, which will hold about four tons of iron in the bar. At the bottom is a long grate for fire. The steel furnace, however, is not well adapted for description. I shall therefore avail myself of an accurate drawing, which was communicated to me by a gentleman conversant with the manufacture, and which is copied in the plate. A layer of charcoal-dust is put upon the bottom of the trough,

* The iron made from the ore found in the neighbourhood of Sheffield, contains a great deal of phosphate of iron or siderite, which renders the metal brittle when cold. I doubt this. T. C.

and upon that a layer of bar iron, and so on alternately until the trough is full. It is then covered over with clay to keep out the air*; which, if admitted, would effectually prevent the cementation. When the fire is put into the grate, the heat passes round by means of flues, made at intervals, by the sides of the trough. The fire is continued until the conversion is complete, which generally happens in about eight or ten days. There is a hole in the side, by which the workmen draw out a bar occasionally, to see how far the transmutation has proceeded. This they determine by the blisters upon the surface of the bars.

If they be not sufficiently changed, the hole is again closed carefully, to exclude the air; but if, on the contrary, the change be complete, the fire is extinguished, and the steel is left to cool for a few days more, when the process for making blistered steel is finished. For small wares, the bars are drawn, under the tilt hammer, to about half an inch broad and three-sixteenths of an inch thick. The change wrought on blistered steel by the tilt hammer, is nearly similar to that effected on iron from the refinery by the forge hammer. It is made of a more firm texture, and drawn into convenient forms for use. German steel is made by breaking the bars of blistered steel into small pieces, and then putting a number of them into a furnace; after which they are welded together and drawn to about eighteen inches long; then doubled and welded again, and finally drawn to the size and shape required for use. This is also called shear steel, and is superior in quality to the common tilted steel. Cast steel is also made from the common blistered steel. The bars are broken, and

* Or with 4 inches deep of moist sand. Indeed the clay should be covered with a layer of sand, to fill up the cracks made by the heat. 100lb. of iron gains half a pound by being converted into blistered steel. T. C.

put into large crucibles with a flux.* The crucible is then closed up with a lid of the same ware, and placed in a wind furnace. By the introduction of a greater or smaller quantity of flux, the metal is made harder or softer.

When the fusion is complete, the metal is cast into ingots, and then called ingot steel; and that which afterwards undergoes the operation of tilting, is called tilted cast steel. The cast steel is the most valuable, as its texture is the most compact, and it admits of the finest polish. Sir T. Frankland has communicated a process, in the Transactions of the Royal Society,† for welding cast steel and malleable iron together; which, he says, is done by giving the iron a malleable, and the steel a white heat; but, from the experiments which have been made at my request, it appears, that it is only soft cast steel, little better than common steel, that will weld to iron: pure steel will not; for, at the heat described by Sir T. the best cast steel either melts, or will not bear the hammer. It may here be observed, as was mentioned before, that steel is an intermediate state between crude and malleable iron, except in the circumstance of its reduction being complete; for, according to the experiments of Reaumur and Bergman, steel contains more hydrogen gas than cast iron, but less than malleable iron;—less plumbago‡ than the first, but more than the latter;—an equal portion of manganese with each;—less siliceous earth than either;—more iron than the first, but less than the second. Its fusibility is likewise intermediate between the bar iron and the crude. When steel has been gradually

* Phil. Trans. 1795.

† Limestone and bottle glass pounded. The limestone is decomposed, and the steel abstracts an additional dose of carbon, from the carbonic acid of the limestone, as is supposed: but I suspect a small quantity of lamp-black is added. T. C.

‡ Rather carbon. Plumbago or black lead is carbon united to a very small proportion of iron. T. C.

cooled from a state of ignition, it is malleable and soft, like bar iron; but when ignited and plunged into cold water, it is the hardness and brittleness of crude iron. From the foregoing facts we are justified in drawing the same conclusions with Reaumur and Bergman, but which have been more perfectly explained by Vandermonde, Berthollet, and Monge, that crude iron is a regulus, the reduction of which is not complete; and which consequently will differ according as it approaches more or less to the metallic state. Forged iron, when previously well refined, is the purest metal; for it is then the most malleable and the most ductile, its power of welding is the greatest, and it acquires the magnetic quality soonest. Steel consists of iron perfectly reduced and combined with charcoal; and the various differences in blistered steel, made of the same metal, consist in the greater or less proportion of charcoal imbibed. Iron gains, by being converted into steel, about $\frac{1}{180}$ part of is weight. In order to harden steel, it must be put into a clean charcoal, coal or cinder fire, blown to a sufficient degree of heat by bellows. The workmen say, that neither iron nor steel will harden properly without a blast. When the fire is sufficiently hot, the instrument intended to be hardened must be put in, and a gradual blast from the bellows continued until the metal has acquired a regular red heat: it is then to be carefully quenched in cold water. If the steel be too hot when immersed in water, the grain will be of a rough and coarse texture; but if a proper degree of heat, it will be perfectly fine. Saws and some other articles are quenched in oil. Steel is tempered by again subjecting it to the action of the fire. The instrument to be tempered we will suppose to be a razor made of cast steel. First rub it upon a grit stone until it is bright, then put the back upon the fire, and in a short time the edge will become of a light straw colour, whilst the back is blue.

The straw colour denotes a proper temper, either for a razor, graver, or pen-knife. Spring knives require a dark brown; scissars a light brown or straw colour; forks or table-knives a blue. The blue colour marks the proper temper for swords, watch-springs, or any thing requiring elasticity. The springs for pen-knives are covered over with oil before they are exposed to the fire to temper.

Explanation of the Plate. Fig. 1. is a plan of the furnace, and fig. 2. is a section of it taken at the line AB. The plan is taken at the line CD. The same parts of the furnace are marked with the same letters in the plan and in the section. EE are the pots or troughs into which the bars of iron are laid to be converted. F is the fire-place; P the fire-bars; and R the ash-pit. GG, &c. are the flues. HH is an arch, the inside of the bottom of which corresponds with the line IIII, fig. 1. and the top of it is made in the form of a dome, having a hole in the centre at K, fig. 2. LL, &c. are six chimneys. MM. is a dome similar to that of a glass-house, covering the whole. At N there is an arched opening, at which the materials are taken in and out of the furnace, and which is closely built up when the furnace is charged. At OO there are holes in each pot, through which the ends of three or four of the bars are made to project quite out of the furnace. These are for the purpose of being drawn out occasionally to see if the iron be sufficiently converted.

The pots are made of fire-tiles or fire-stone. The bottoms of them are made of two courses, each course being about the thickness of the single course which forms the outsides of the pots. The insides of the pots are of one course, about double the thickness of the outside. The partitions of the flues are made of fire-brick, which are of different thicknesses, as represented in the plan, and by dotted lines in the bottom of the pots. These are for sup-

Steel Furnace.

Fig. 2.

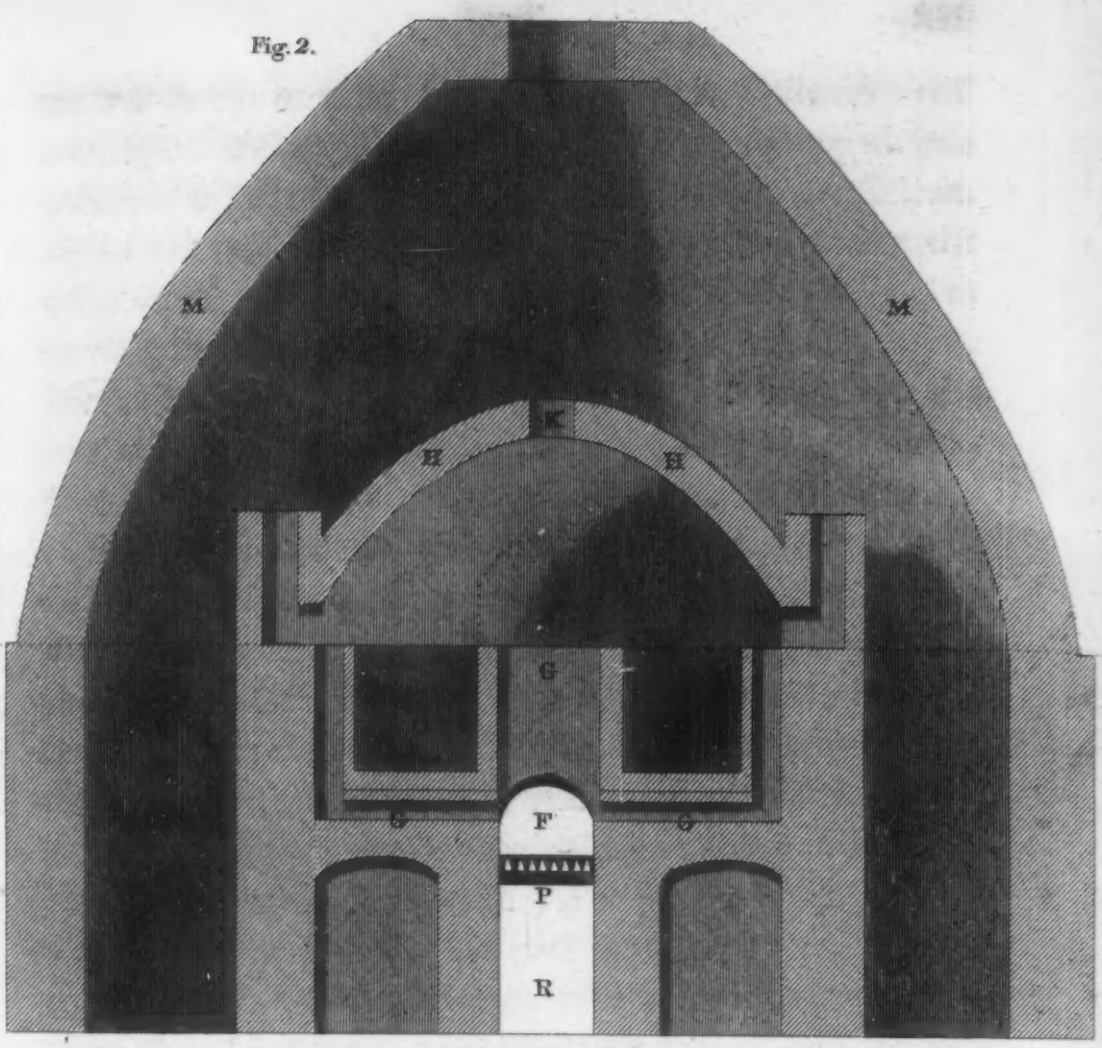
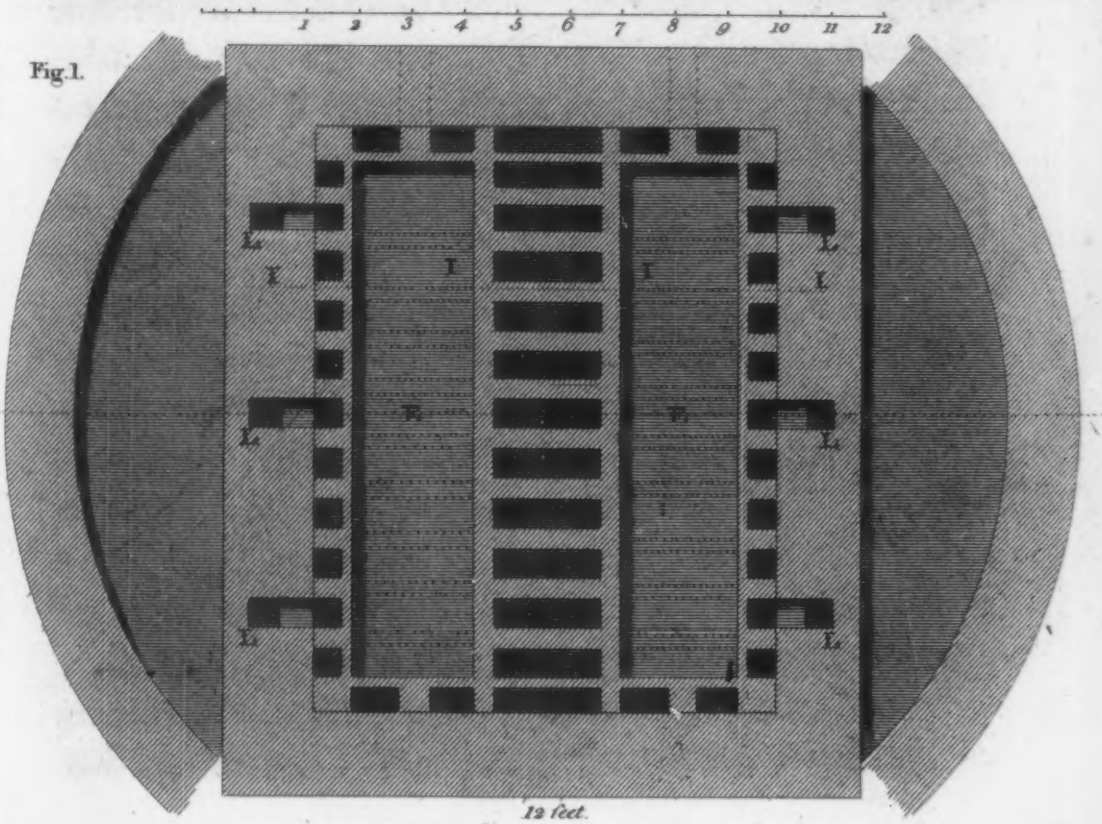


Fig. 1.



12 feet.

porting the sides and bottoms of the pots, and for directing the flame equally round them. The great object is to communicate to the whole an equal degree of heat in every part. The fuel is put in at each end of the fire-place, and the fire is made the whole length of the pots, and kept up as equally as possible."

On this paper of Collier's it may be remarked, that the bars are often put into iron as well as brick or earthen cases, and indeed in England generally so—that although the heating and cooling may occupy altogether a dozen days, it does not require more than a dozen hours of *white* heat, to convert into good blistered steel, bar iron the 8th of an inch thick—that steel of cementation, blistered or German bar steel, should be made of the very best, and best worked iron that can be procured; generally of Swedish iron, the whole of which used to be bought up by 2 or 3 houses in England. If not well hammered in its state of iron, it will shew the want of uniformity in its texture, much more as steel——Cast steel is always made originally from bar steel, or steel of cementation——equal proportions of limestone and cinders, is far too much of limestone: one part of limestone to 3 or 4 of cinders is more common; and the English rich Cumberland ore, worked with wood charcoal, requires no more than one twentieth of limestone—there is hardly any such thing in use at an English blast furnace as bellows; they are supplied with air either from cast iron drums or cylinders worked with the power of water or steam; or by a water blast; and the air is condensed so as to support a column of 6 inches of mercury; by which compression from 15 to 1800 cubic inches of air will pass through the discharging pipe of 3 inches wide in a minute——Mr. Collier has not noticed the common process of puddling introduced by Mr. Cort, which has succeeded in practice; and

of which Dr. Beddoes has given a detailed account in the 5th volume of the Manchester Transactions.

Process of making Steel at Newcastle, in England.

1 Jars Voyages. Metallurgiques, 221.

"There are several steel furnaces at Newcastle of different sizes, but similar proportions. The mason work of the cementing furnace, is an oblong square. A fire-place with bars passes the whole length. This grate, 20 inches wide, is nearly on a level with the ground; the ash-hole is underneath. Sixteen inches above the grate on each side are placed the cases wherein the bars are arranged that are to be converted into steel. For this purpose ten flues are worked into the wall of those crucibles or cases on each side of their length; they are of fire-brick and cemented with loam well beaten and worked. The inside dimensions of the cases are 10 1-2 feet long, 2 feet 4 inches wide, and 2 feet 6 inches deep. The flame circulates all round the cases, whose sides are supported by walls that enable them to sustain the weight of iron within. An arch is thrown over the cases and fire-place in order that the flame may reverberate on the top of the cases. The flame and smoke passes out at eight openings. The whole communicates with one common chimney of a conical form. The cases are of hewn fire-stone.

No iron is used for the purpose of steel but Swedish iron.

The iron bars are cut to the length of the inside of the cases: they are of different breadths, from an inch and a half to two inches and an half, and from four to seven lines thick, (12 lines make an inch.) Each case can hold ten tons of iron of 21 cwt. of 112 lbs. each to the ton.

The only substance used is charcoal dust:* neither oil nor salt. The bottom of the cases are covered with charcoal dust sifted through a coarse sieve, and slightly

* I believe animal substances are frequently added. T. C.

moistened, about an inch thick: in this the bars are laid side by side with about 1-4th inch of charcoal dust between each bar. This layer is covered with half an inch of charcoal dust, and this again with a layer of bars. The last layer is covered with 2 inches of charcoal, and this with a coating of clay, or of moistened sand. The sand is raised up high in the middle where it is about 10 inches thick. If the charcoal were exposed to the air, it would burn away. The walls at the breadth of the cases are now built up, leaving only a hole in the middle of each, stopped up with loose brick, big enough to take out a trial bar. The mouth of the fire-place at each end is also built up so as to leave only an opening of about 10 inches by 8 to feed the grate with fuel and stir the fire; this hole is shut by an iron plate as a door; so that the air ascends up the ash-hole and through the bars to maintain the fire. The fire is generally lighted on Monday evening, and is kept up as hot as can be from thence till Saturday night, which is about the time that ten tons of iron takes to be converted into steel. If there be more than ten tons, the fire is put in on Sunday night. Toward the latter end of the time, the trial bar from the middle of the cases at each end is examined. When the process is over, the fire is drawn, by removing the moveable bars between the fixt bars of the grate, so as that the fuel tumbles into the ash-hole. The whole then is left to cool, which takes near a week more. They calculate to burn from 16 to 18 fodder of coal, each fodder weighing 16 cwt. and being worth four shillings sterling, or from 250 to 290 cwt. of coal. They say the iron neither gains or loses in weight by the operation. This is *blistered* steel, and sold (the volume bears date 1774) at 26 to 28 shillings the cwt.

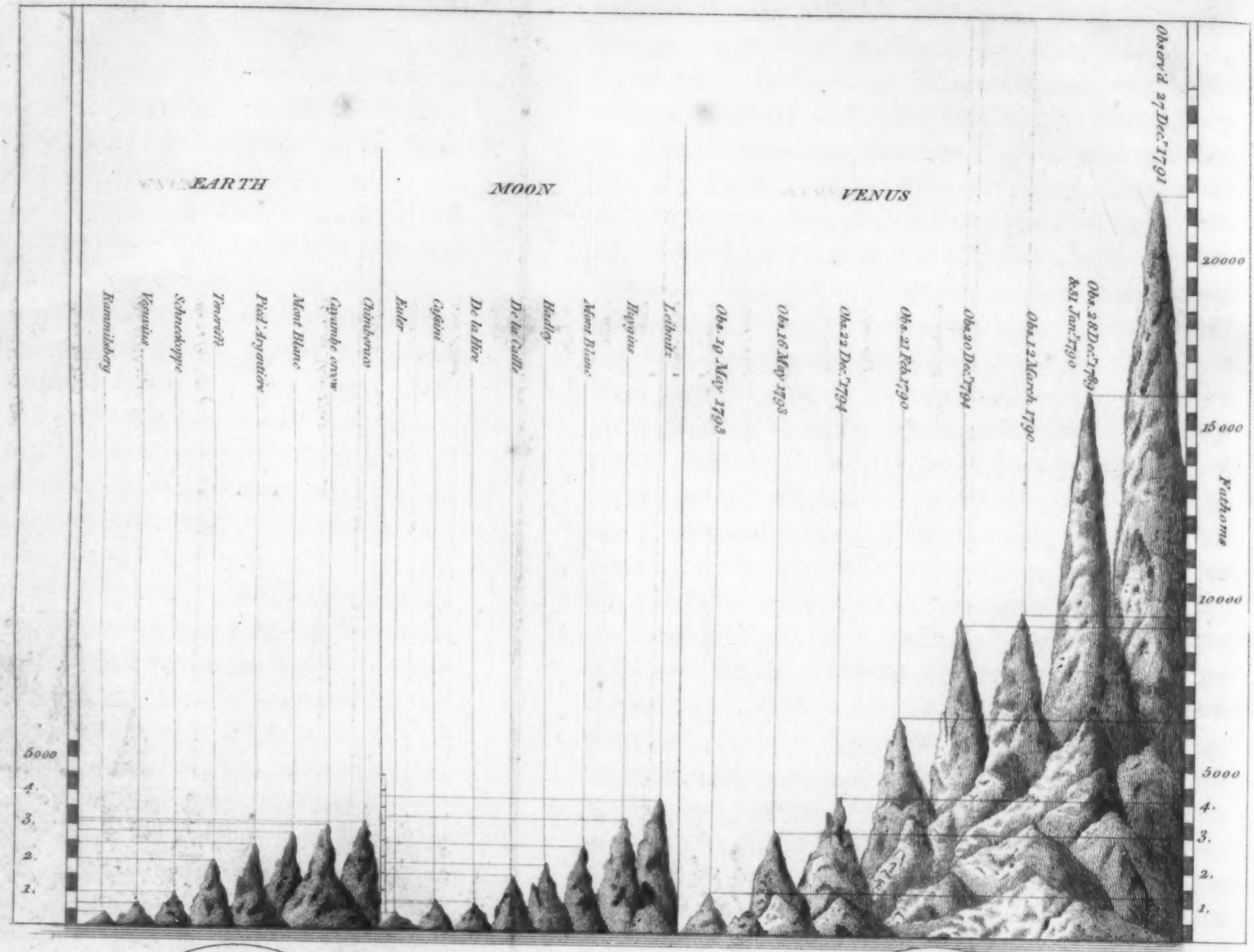
These flat bars of steel, when cold, are drawn into square bars, of about 3-4ths of an inch thick, which are

suffered to cool in the air, without being plunged in water. This greatly improves the appearance of the grain, which before it has undergone the tilt hammer, has a large grained fracture more like brittle iron than steel. This is *common* steel, used for files, saws, scissars, knives, &c. It fetches from 30 to 32 shillings the cwt. The ends of each bar, where the steel is usually not of so good quality as the rest, are cut off, and these are forged together into bars and made up in bundles or faggots under the denomination of *soft* steel, which answers for plough-irons, the edges of spades, &c. and common blacksmiths' work.

To make (or rather to imitate) *German* steel, they take a truss of ten or a dozen bars of blistered steel, they heat them together, covering them with dry clay in powder, which seems to concentrate the heat, and prevent the action of the air; the bars are then taken out, and well worked together under the hammer, and then drawn out into bars of a convenient size. This produces a perfect imitation of the real German steel in appearance and quality, and is in fact the same process as is used for the best steel in Styria. The heat is given by coke; but it would perhaps be better with charcoal; indeed some manufacturers take the blistered steel, heat it as above with charcoal, draw it out into German steel, then cement it over again with charcoal dust as is done to iron in the first instance; they then again draw it out into bars.

Other manufacturers, take pieces of old files, and refuse steel of all kinds, and melt them in a crucible with a flux, of which they make a secret." Thus far Jars's account.

(To be continued.)


EARTH
Observd 27 Dec.r 1791
MOON
Leibnitz
Bayeus
Mont Blanc
Hadley
De la Caille
De la Hire
Cassini
Euler
Chimborazo
Cayambe orvw
Mont Blanc
Pic d'Aryantiere
Teneriff
Schneekoppe
Vesuvius
Kammilsberg
VENUS
Obs. 21 Feb.y 1790
Obs. 22 Dec.r 1794
Obs. 16 May 1793
Obs. 19 May 1793
Obs. 30 Dec.r 1794
Obs. 12 March 1790
Obs. 28 Dec.r 1789
& 31 Jan.y 1790
20000
15 000
Fathoms
10000
5000
4.
3.
2.
1.
5000
4.
3.
2.
1.
Tiebout sc.
EARTH
MOON
VENUS

On the Comparative Height of the Mountains of the Earth, the Moon, and Venus.*

SCHROETER, the learned astronomer of Lilienthal, who has several excellent telescopes by Herschel, published some time ago a work on the height of the lunar mountains, as compared with those of the earth; and lately he has published a new work on the height of the mountains of Venus. Faujas, who not long ago undertook a journey into Germany, of the utmost importance to the sciences, brought back with him these two works of Schroeter. We there see the manner in which that indefatigable astronomer makes his observations. It is by the projection of the shadows formed by these mountains when they begin to appear on their horizon in regard to us, or when they are about to disappear below the horizon. He distinguishes the mountains into different orders.

The plate in Schroeter's work consisted only of outline, and he expressed the diameter of the three globes merely by straight lines. The annexed delineation (See Plate) was drawn by Alexander Faujas, the son, who to military talents unites a stong attachment to the sciences. He has rendered the height of the mountains more just, and, from his drawing the respective magnitude of the three globes can be better estimated. It is here seen that the moon, which is about forty-nine times smaller than the earth, has mountains more than 4000 toises in height†; while that of Chimboraco, one of the Andes in South America, the highest mountain of our globe, is little more than 3000. Venus, which is less than the earth by a ninth has mountains 23,000 toises in height. It must here be remarked, that the highest mountains on these three globes appear all to be volcanic.

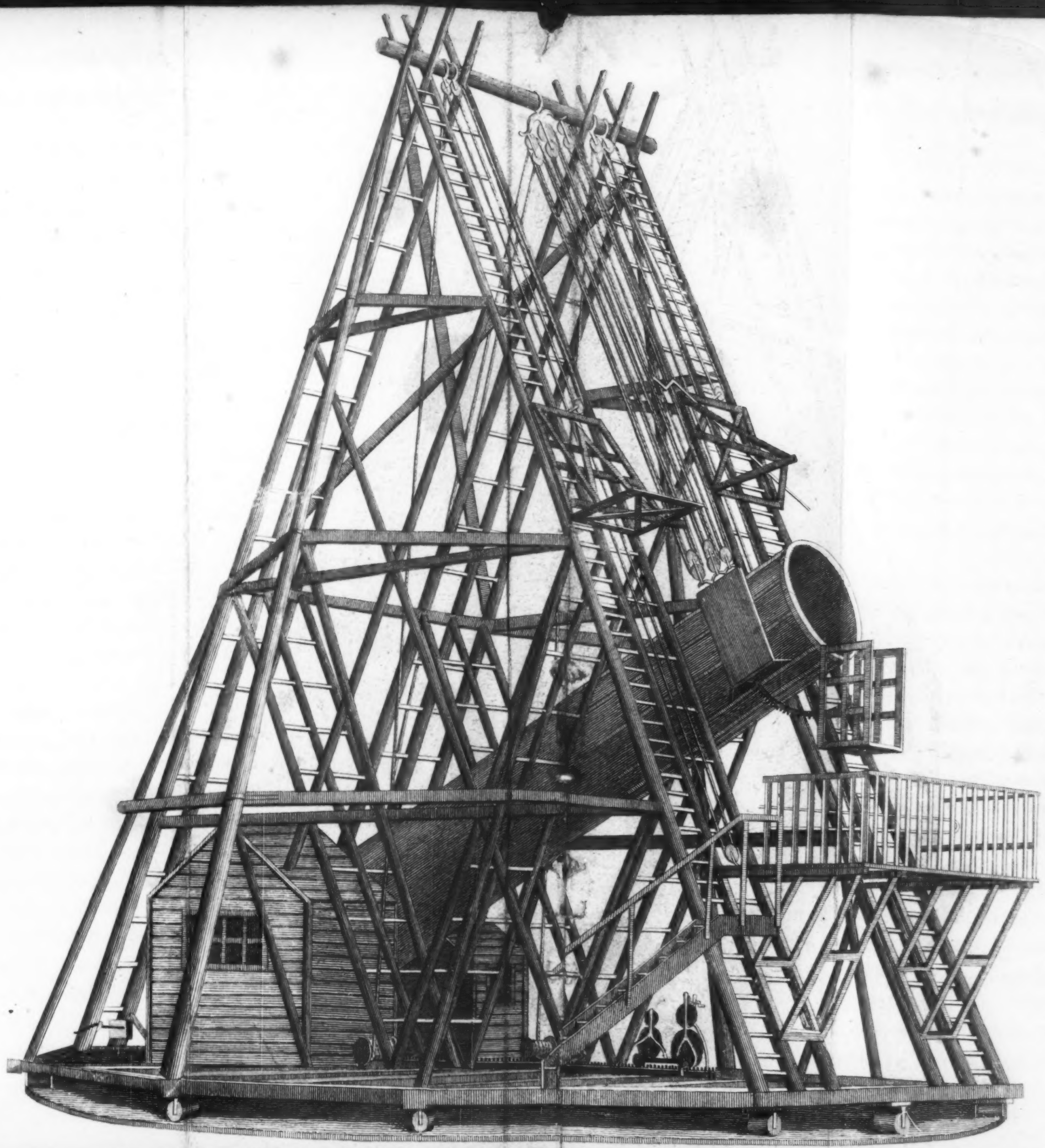
* From the Journal de Physique, Prairial, An. 7.

† The French toise is to the English fathom as 1 to 1·0664.

Description of Herschell's Forty-foot Reflecting Telescope, Accompanied with an Engraving.

THE Telescope is placed in a situation due north and south, and the plate delineates the whole apparatus as seen by a person placed at a convenient distance from it towards the south-west. From this view the structure is sufficiently understood; and, with very little attention, the mode of pointing this immense body to any part of the heavens will be clearly seen. We shall treat of the chief parts in their order; and first, of the tube itself.

The tube is made of rolled or sheet iron joined together without rivets, by a similar seaming to that which is used for iron funnels for stoves; the thickness of the sheets is somewhat less than a 36th part of an inch, or it may be found more accurately by taking a square foot of it at the weight of fourteen pounds. Great care was taken in so joining the plates of which the tube is composed together, that the cylindrical form should be secured, and then the whole was coated over three or four times with paint, inside and outside, to secure it against the damp. The tube was formed at a short distance from its present place, and removed with great ease by twenty-four men, divided into six sets; so that two men on each side with a pole of five feet long in their hands, to which was affixed a piece of coarse cloth, seven feet long, going under the tube, and joined to a pole of five feet long, in the hands of two other men, assisted in carrying the tube. The length of the tube is 39 feet 4 inches, the diameter 4 feet 10 inches; and, upon a moderate computation, it is supposed that a wooden tube for the same purpose would have exceeded this in weight by at least 3000 pounds. The length of the iron plate forming the tube, and composed of smaller ones 3 feet 10 inches long and 23 1-2 inches broad, is nearly 40 feet, and the breadth 15 feet 4 inches.



The great mirror which, by proper methods, was brought to the lower part of the tube, is made of metal, 49 1-2 inches in diameter; but the concave part, or polished surface, is only 48 inches in diameter. Its thickness is 3 1-2 inches; and, when it came from the cast, its weight was 2118 pounds, of which a small quantity must have been lost in polishing. An iron ring, 49 1-2 inches in diameter, within 4 inches broad, and 1 1-8 inch thick, with three strong handles to it, goes round the mirror, and a flat cover of tin is made to correspond to this ring that the mirror may be preserved from damp; and, by an easy contrivance, it is taken off and fixed on at pleasure.

At the upper end, the tube is open, and directed to the part of the heavens intended for observation, to which the observer's back is turned, and, he standing on the foot-board visible in the plate, looks down the tube, and perceives the object by rays reflected from the great mirror, through the eye-glass at the opening of the tube. Near the place of the eye-glass is the end of a tin pipe, into which a mouth-piece may be placed; so that, during an observation, a person may direct his voice into this pipe, whilst his eye is at the glass. This pipe is 1 1-2 inch in diameter, runs down to the bottom of the tube, where it goes into a turning joint, thence into a drawing tube, and out of this into another turning joint, from which it proceeds by a set of sliding tubes towards the front of the foundation timber. The use of this tube is to convey the voice of the observer to his assistants; for at the last place it divides itself into two branches, one going into the observatory, the other into the workman's room, ascending in both places through the floor, and being terminated in the usual shape of speaking-trumpets. Though the voice passes in this manner through a tube with many inflections, and not less than 115 feet, it requires very little exertion to be well understood.

To direct so immense a body to any part of the heavens at pleasure, much ingenuity, and many mechanical contrivances are evidently necessary. The whole apparatus rests upon rollers, and care was previously taken of the foundation in the ground. This consists of concentrical circular brick walls, the outermost 42 feet, the innermost 21 in diameter; 2 feet 6 inches deep under ground, 2 feet 3 inches broad at the bottom, and 1 foot 2 inches at the top, capped with paving-stones, about 3 inches thick, and 12 3-4 inches broad. In the centre is a large post of oak, framed together with braces under ground, and walled fast with brick-work, to make it steady. Round this centre, the whole frame is moved horizontally, by means of 20 rollers, 12 upon the outer and 8 upon the inner wall.

The vertical motion is given to the telescope by means of ropes and pullies, as seen in the plate, passing over the main-beam, supported by the ladders. These ladders are in length forty-nine feet two inches; and there is a moveable gallery with twenty-four rollers to ease its motion. The small stair-case visible in the plate, is intended for persons who wish to ascend into the gallery, without being obliged to go up the ladder. The ease with which the horizontal and vertical motions may be communicated to the tube will be best conceived from a remark of HERSCHELL, that, in the year 1789, he several times observed Saturn two or three hours before and after its meridian passage, with one single person to continue at his directions the necessary horizontal and vertical motions.

Upon the platform are visible two rooms, the one called the Observatory, eight feet five inches, by five feet five inches, the other called the Working-room six feet six inches by four feet five inches. To persons in these rooms, as has been above remarked, the observer can give his directions by means of the speaking- pipes; and in

the rooms may be placed things, commonly used in Observatories.

From a view of the plate and a description thus given of it, our readers, we presume, will form a competent idea of an instrument, which, with proper eye-glasses, magnifies above six thousand times, and is the largest that has ever been made. Astronomers in different parts of the world may be discouraged from continuing their observations, when it should seem, that their discoveries must be anticipated by HERSCHELL; but though he has so much the advantage, much is left to their labour and industry. It did not require a telescope of this magnitude to observe the object which was first discovered to be a planet by this Astronomer, for it had been seen and taken for a fixed star by many persons in the two last centuries. And the double ring of Saturn, which has, indeed, been so beautifully observed through HERSCHELL'S magnifier, had been already described by Cassini in his Memoirs. Such of our readers as wish for a more accurate account of this instrument, will find it in the Transactions of the Royal Society for 1795, second part; in which there are eighteen plates and sixty-three pages of letter-press, to give an ample detail of every circumstance relating to joiners' work, carpenters' work, smiths' work, &c. which has attended the formation and erection of this instrument. It was completed on August 28th, 1789, on which day the sixth satellite of Saturn was discovered.

EVAPORATION IN VACUO.

Some account of experiments in France, in prosecution of Professor Leslie's discovery of the method of congelation by means of a vacuum.

It will be proper to give some previous account of what has already been done by professor Leslie, before I introduce the following paper from the Journal de Physique, of October 1812.

The effects of evaporation in producing cold have long been known. Dr. Cullen and Dr. Bryan Higgins applied ether for this purpose by moistening slowly the bulb of a thermometer. Higgins, by this method, reduced the mercury to 40 of Fahrenheit. Cavallo invented a very simple and ingenious apparatus for freezing by means of ether.

In 1795 Mr. Oliver Evans suggested the possibility of freezing water by means of evaporation of ether *in vacuo*, but he does not appear actually to have made the experiment, though he has suggested the means.

In 1810 or very early in 1811, Professor Leslie, in making some experiments in relation of air and moisture, succeeded in freezing water in vacuo, by causing the vapour raised from the water to be absorbed by strong sulphuric acid, the water being contained in a small shallow dish about two inches above the surface of the acid: and in the beginning of 1812 by means of an apparatus connected with an excellent air pump, he succeeded in freezing mercury, by moistening the bulb of a thermometer with water, repeatedly, until the effect was produced. Soon after his first experiment, he proposed to apply the principle in the large way to the production of ice, the concentration of juices, the drying of gunpowder, &c.

In 1811 M. M. Clement and Desormes, in France, proposed also the application of the same principle to the

same purposes: a brief account of their memoir from Cuvier's report of the discoveries of the year 1811, I published in the Port Folio, for September 1812.

The following paper presents us with a new and ingenious method of producing similar effects, by means more adapted to common use. I have translated it for this work. T. C.

From the Journal de Physique, of October 1812.

Notice of the effects of evaporation in vacuo, and on the means of producing a vacuum without employing an air pump, by M. Honorè Flaugergues.

The academy of sciences, belles lettres and arts at Lyons, proposed in 1811 as the subject of a prize "The developement of the theory of the congelation of water, by the vacuum of an air pump, and of the phenomena accompanying this experiment: and also to determine its application to economical uses; whether for the purpose of obtaining ice at all seasons and in all places, or of desiccating viands, and milk, and inspissating the juices of fruits."

One of the silver medals was decreed by the society to M. Configliachi, professor of Philosophy at Pavia, for a memoir presented by that gentleman, which contained a luminous theory and beautiful experiments. It is sufficient to mention here, that the learned Professor had contrived by means of an excellent air pump to make a vacuum so perfect, that the simple congelation of water therein, produced a degree of cold nearly approaching to that, which with the assistance of mercury had equalled the degree of congelation of mercury; and at length by employing ether instead of water, the mercury became solid in the midst of summer, and the degree of cold reached to 41 below Zero of Reaumur's Thermometer.

The society also did me the honour of presenting me

with a silver medal for some economical views of this subject that I submitted to their consideration. A good air pump, is an instrument too expensive and too scarce for common use; and it requires also much attention when used. Nor can it be applied to operations in the large way. I have therefore endeavoured to supply its place, by a method sufficiently plain and simple to be within the reach of every body, *by exhausting a vessel of air by means of steam, and then causing that steam to be absorbed by sulphuric acid, by dry pot ash, or by quick lime, and preventing the external air from entering the exhausted vessel.* It is evident that such a vessel ought to remain empty of air; and that the vacuum will be more perfect in proportion as the estimate of the air has been more exact. But I have found by means of several experiments made with the utmost care, that by causing a small quantity of water to boil in a vessel, the air may be expelled and a vacuum formed so nearly perfect, that the remaining air would not occupy a space greater than the 4645th part of the capacity of the vessel: an approximation which no air pump has yet equalled. Few air pumps even under favorable circumstances are able so to rarify the air, as to lower the mercury of a manometer half a line below its level; while in air rarified to the degree above mentioned, the mercury would stand at 0,073 only above its level. (A manometer or manoscope, is an instrument contrived to measure the *density* of the air: the barometer measures only the *weight* of the air.)

For the purpose of repeating the well known experiment of Mr. Leslie, on the congelation of water in vacuo, by the means I propose, we may proceed thus. Take a bell glass or any glass receiver; drive out the air by boiling in it when turned upside down, a small quantity of water, or by placing it on a trough full of boiling water, or by introducing under it or withinside, any body brought

to the state of incandescence whereon you may project a few drops of water: so soon as it is completely filled with steam, turn it quickly with its mouth downward upon a plate or dish whereon you have previously placed two capsules, the one containing concentrated sulphuric acid, the other water. There should be a border of wax softened with turpentine into which the edge of the inverted bell glass should be pressed, to exclude the access of external air; and the wax should also be pressed close to the edge of the glass. The oil of vitriol will soon absorb the vapour, and if the experiment has been neatly conducted, the other capsule containing water, will exhibit the paradoxical appearance of ice formed by the means of boiling water.

The advantage of being thus able to procure ice at all seasons and in all situations, may be considered as more curious than useful. But a method of operating in the large way upon the same principle, without the aid of an air pump, and by means of which meat, fish, milk, &c. may be dried, the juices of fruits and saline solutions concentrated so as to serve the purposes of general convenience, is what I mean to propose.

I have discovered that steam may be raised by throwing water on ignited substances, and that steam may be absorbed by substances proper for the purpose in large boxes or chambers. The vacuum thus produced will remain a considerable time, provided the boxes are exactly jointed, made of compact wood, and covered on the outside with three or four coats of fat varnish, or amber varnish. Nor will the pressure of the atmosphere pass through a stone wall, if made of vitrifiable stones (quartzose) or of basalt, cemented by mastic: (that is I presume not varnish made of mastic, but any resinous cement.) Hence for the purpose of using this new method of desiccation, *cold stoves* may be employed, where the subjects will

be dried more readily than by means of fire, and will not experience those changes which the action of heat never fails to produce. Moreover, this method of evaporating requires hardly any expence, for the sulphuric acid or the potash made use of, need only be exposed to fire to drive off the moisture they have imbibed, without any loss of the articles themselves.

This new method of evaporating in vacuo, may also be applied with success to the distillation of spirituous liquors, as I have satisfied myself by some trials made with this view. Having by means above described driven out all the air contained in the head of an Alembic to the beek of which I had luted a matrass, I placed the head upon a plate whereon there were also placed a capsule full of sulphuric acid, and another of weak spirit of wine. I carefully luted the junctures, the spirit of wine was raised in vapour, the watery part or phlegm was absorbed by the acid of vitriol, and the rectified spirit was distilled into the matrass by the sole heat of the atmosphere, which was at that time from 18 to 20. (72 to 77 of Fahrenheit if Reaumur's scale be meant, and 64 to 68 of Fahrenheit if Celsius's or the Centyrade thermometer be meant. I am in doubt which is referred to here.)

This method of distilling by evaporation without fire, seems to me too much neglected at a time when the scarcity of fuel renders it desirable to diminish the consumption as much as possible. (Mr. Watt while making experiments on steam during the invention of the improvements made on the steam engine by himself, made also many experiments to distill in vacuo, but without success in a large way. T. C.)

NUTRITION OF VEGETABLES.

Of all the investigations hitherto published on the Theory of Vegetation, I know of none that furnishes results so curious, or so important to Vegetable Physiology, as the following paper of M. Bracannot "On the Assimilating Power of Vegetables:" abridged from the Annales de Chemie, vol. lxi. p. 187. *Feb.* 1807. *The experiments must be varied and repeated, before they can be considered as conclusive. But should they be found true, they will go a great way to induce us to believe, that potass, and even carbon, are compounds, and products of vegetable organization formed out of oxygen, hydrogen and light. See* 18 *Nich. Jour.* 15.

PHYTOLOGISTS for a long time imagined, that vegetables were nourished by certain juices, which they extracted ready formed from the earth. Van Helmont in great measure refuted this by his celebrated experiment. In a box containing 100 lbs. of earth, and covered with lead, he planted a willow, weighing 50 lbs. This he watered with distilled water, and in five years it had acquired an addition to its weight of 119 lbs. 3 oz. without any perceptible diminution of the earth. The experiments of Boyle with earth baked in an oven, and those of Duhamel and Bonnet with moss,* prove the same thing.

Other natural philosophers have pursued the same inquiry: Tillet, in particular, made a number of experiments, to ascertain whether water and air were the only substances necessary for the growth of plants. He filled several pots with different earthy matters, some with old plaster, others with pure river sand, fragments of stone broken to powder, &c.; buried them partly in the ground, to retain the moisture; and sowed wheat in them. The wheat produced very fine ears; and the grains, being sown, produced other fine plants.

From the infant state of chemistry, at the time, however, none of the plants produced by means of air and water alone were analysed. This indeed has since been done; and it has been advanced, that plants growing in such a manner as to have been nourished by water alone, did not furnish as much carbon as was

* Mr. Procopius Densidoff of Moscow, sows seeds in moss, where they germinate, and then plants them in pots. In this way he loses very few seeds of those that grow with most difficulty. *Note of Prof. Willmett.*

contained in the seeds from which they sprung; while those in mould were much more vigorous, in consequence of the carbon with which it furnished their roots. But these experiments were on too small a scale to furnish satisfactory results; and I have therefore attempted to investigate the subject anew, in order to ascertain, how far this opinion is well founded.

As a preliminary step, I conceived it necessary to analyse vegetable mould in a state of perfect decomposition. For this purpose I selected perfectly pure, black, pulverulent mould, from among the hollow roots of a very old tree. Distilled water, in which it was boiled, remained colourless after filtration, and on being evaporated left no sign of any soluble matter.

A hundred grammes [$3\frac{1}{2}$ oz.] were reduced by dessication to 20, which shows it to be extremely retentive of water.

These 20 gr. distilled at a red heat, gave out 4 of water, that powerfully reddened infusion of litmus; and contained empyreumatic acetous acid, partly saturated with ammonia; 2 of an acrid oil, that congealed on cooling, and was of a dark brown colour; 89 cubic inches of oily hydrogen gas, burning with a blue flame; and 34 cubic inches of carbonic acid absorbed by lime.

The coally residuum weighed 8·5 grammes, which were reduced by incineration to 2·4 gr. of light yellow ashes.

Boiling distilled water digested on these ashes acquired no peculiar taste, did not turn syrup of violets green, and was barely rendered turbid by the addition of a few drops of oxalic acid, which seemed to indicate, that a few particles of lime had been set free by the calcination. The nitrates of barytes and of silver produced no change in it. On farther analysis these ashes afforded 1·3 of a gr. of silex, ·2 of oxyde of iron containing a little oxyde of manganese, ·25 of phosphate of lime, ·2 of lime, and some traces of magnesia.

I boiled 6 gr. [92 grains] of the same mould for an hour, in a strong solution of caustic potash, when it became glutinous, and swelled up. I then diluted it with water filtered, and obtained a very deep brown liquor. This mixed with the lixiviating waters gave on the addition of an acid a precipitate, that weighed 1 gr. when dried. It was of a very black colour, and in little shining scales. Scarcely any vapour arose from it when thrown on burning coals, and I consider it as charcoal well saturated with hydrogen Art may imitate this substance, by effecting by fire what nature does by time. If we deprive a vegetable substance

of almost all its oxygen, and a small quantity of its hydrogen, by exposing it to a certain temperature, the result will be a hydroguretted charcoal, partly soluble in potash, as I have found by experience.

That part of the mould, which had resisted the action of potash, weighed when dried 5 gr. It had no longer the physical characters of mould; was in pieces that were tolerably hard and brittle; and had a striking resemblance to pitcoal, which led me to produce it in larger quantity. In this way it had still such a resemblance to coal, that I could compare it to nothing else.

From this examination of mould it appears, that it cannot supply plants with any soluble matter for their nutrition, since boiling water has no action on it. It would be superfluous to say, that seeds sowed in it vegetated with extraordinary vigour; but I must not omit to mention the presence of a large quantity of potash in the plants, though I could not detect any in the mould in which they grew, by the most strict researches.

These observations appear to corroborate the opinion of Tillet and Parmentier, who consider manure as useful only by retaining moisture, and keeping strong soils open for some time, so as to allow the roots of plants to penetrate them. But if water and air be the only sources of the food of plants, any insoluble matter, sufficient in quantity, and duly watered, must be adequate to the purpose of their growth. This I endeavoured to ascertain by experiments.

Exp. I. In a box filled with pure litharge I sowed 400 seeds of white mustard, weighing 2·2 gr. These I watered frequently and carefully with distilled water. The box was placed in a good aspect, and a glass was hung over it to keep out the dust. The plants throve very well, and produced perfect pods. I collected all the seminal leaves as well as the rest that dropped off; and when the vegetation was at its height, pulled up the plants. Having well washed the roots, to remove any portions of oxyde of lead, and wiped them dry, the whole weighed 264 gr. After they were dried, the weight was 34·2 gr.

These yielded 12 gr. of coal, which by incineration were reduced to 4·2 gr. of ashes. These lost by lixiviation 2·2 gr.; of which ·59 gr. were sulphate of potash, ·69 gr. potash. The insoluble residuum afforded ·4 gr. of silex; ·45 gr. of oxyde of iron, alumine, and phosphate of lime, the proportions of which were

not determined; ·57 gr. of oxyde of iron; and a very small portion of magnesia.

Exp. II. In a very large, deep, and perforated bowl of stone ware, filled with well washed flowers of sulphur, 250 seeds of white mustard were sown. The whole was covered with a large bell glass, allowing free access to the air and light. The plants grew vigorously, being frequently watered with distilled water; as sulphur, having little affinity with water, parts with it very easily, and dries on the surface. They produced flowers in tolerable abundance, and the seeds produced plants in common ground. The weight of the fresh plants, with the fallen leaves, was 108 gr.; and when dried 18·6 gr. Their coal weighed 7·8 gr. and left 1·55 gr. of whitish ashes, which afforded by lixiviation ·6 gr. of carbonate and sulphate of potash. The insoluble part was similar to that of the former.

Exp. III. A hundred seeds of white mustard were sown in twenty pounds of very small unglazed shot, on the 9th of July. On the 28th of August they began to flower, and afforded small pods. All these plants were slender, and had but few and small leaves. When fresh they weighed 10 gr. and after being dried 2.3 gr. they yielded very little coal, but more than the weight of the seed. The weight of the shot appeared to oppose too great an obstacle to the young roots, as most of them spread over the surface, without being able to penetrate it. The little affinity of the lead for water was another reason of the feeble growth of the plants; and hence I have found, that plants thrive less in metallic powders, than in their oxyds.

Exp. IV. On a flat stone pavement a bed was formed, about a yard high, of fine sand, taken immediately from the bed of the river, and well washed. In this were sown seeds of the common radish (*raphanus sativus*) which were frequently watered with perfectly pure rain water, and the plants grew with as much vigour as they would have done in any ground. The greater part of the radishes were brought to table, and were of a very delicate flavour, without any of the disagreeable earthy taste they have sometimes. Some of them were left to seed; and most of these grew to the height of 2 feet or $2\frac{1}{2}$. It was observed, that those at the top of the heap were much larger and stronger than those near the bottom.*

* A skilful gardener informs me, that asparagus too will succeed very well in pure river sand. Potatoes also grow well in sand, and are said to be better tasted.

Sixty-three of these plants when dried weighed 372 gr. Incinerated they left 54.2 gr. of gray ashes. These afforded by lixiviation 18 6 of very fine potash. From this I am inclined to think, that the radish might be cultivated with advantage on wet sandy places by the sea shore, for the purpose of fabricating potash.* These 18.6 gr. being farther analysed, were found to contain 6·7 of pure potash; 7·35 of sulphate of potash; a small quantity of phosphate of lime; and the rest was carbonic acid.

The residuum left after lixiviating the ashes appeared to contain sulphur, as on pouring nitric acid over it sulphuretted hydrogen was given out; but I could not find any phosphoric acid in it. I did not examine it for the earths, as these might have been said to have been taken up from the sand.

* It appears, that potash abounds in all the plants of the class tetradynamia, and the ashes of some of the species were long in use for making soap and glass, before the introduction of soda as an article of trade. According to Bomare, the bunias cakile, sea rocket, was much employed for these purposes.

I must here add an observation, which appears to me pretty general, and which I made in examining the acrid and bitter properties of plants. One or other of these principles I have almost always found in conjunction with a large quantity of potash, which was frequently saturated with nitric acid. Thus among the cruciferous plants, which are all more or less acrid, the sisymbrium nasturtium, common water-cress, afforded me a great deal of alkaline matter after incineration; and when fresh I found in it nitrate of potash. I have observed the nitre melt on incinerating cabbages and turnips; and Mr. Delaville found this salt in large quantity in the sap of these plants. Mr. Bouillon-Lagrange found a large quantity of potash in the ashes of the erigeron canadense, Canada fleabane, which is acrid. The ashes of tobacco, the acrimony of which is well known, yield 40 per cent. of potash. Among the bitter plants I have examined, I found nitrate of potash in the fumitory, 100 parts of the ashes of which contain more than 36 soluble in water, according to Wiegleb and Rukert. The common centaury, marsh and Siberian trefoil, and different species of the genus centaurea, which are very bitter, afford ashes in which potash abounds. Whether in these plants it be saturated with nitric acid I have not ascertained. I must observe, however, that I have found no nitric acid in wormwood, 100 parts of the ashes of which afford nearly 75 of saline matter, according to Wiegleb. This large quantity of alkali has appeared to me to be partly saturated with a peculiar matter, which is deposited by a decoction of the fresh plant, and may be precipitated abundantly by nitrate of lead. This matter dissolves very well in alkalies neutralizing part of their properties: it is the same that Mr. Vauquelin has found in some species of cinchona. Does it exist in all bitter plants? and is it this which in cinchona and worm-wood cures intermittent and low fevers?

Having thus examined these plants, I thought it might not be amiss to compare their produce with that of some others, which had grown in common garden mould. Of these dried 372 gr. afforded but 34 of ashes which it is true were very saline, and yielded 16 gr. of saline matter, consisting of carbonate and sulphate of potash. In the incineration of these plants too I observed a very copious production of ammonia, on pouring a little water on their ashes while still hot.

But whence come these earths, alkalies, acids, metals, sulphur, phosphorus, found in plants, that have had no aliment but pure water? Can vitality, in conjunction with light and heat, determine certain quantities of oxygen and hydrogen to form by peculiar condensations those substances which have been considered as simple? this might put us on examining in a new point of view all those substances, that chemistry has not yet been able to decompose, and thus perhaps the conjectures, that have been advanced by some, may be verified.

We may even extend these remarks to animalization, supported by the well known experiment of Rondeletius, who kept a fish in pure water, till it grew too large for the vessel containing it, and by other similar experiments on different animals. It would even seem, that food acts on the stomach in a great measure as mould does on the roots of plants, merely retaining water in such a state of division, as to fit it for absorption and assimilation.

From what has been said it appears, that foreign matters dissolved in water only check the progress of vegetation; but that the vital powers can sometimes surmount these obstacles, appropriating only the pure water, that held these matters in solution.

If experiments founded on long practice were still necessary to prove, that the soil is so much the more proper for vegetation in proportion as it is deprived of soluble foreign matter, I would mention the practice of paring and burning wastes, used chiefly in England. Lands thus treated remain in heart a long time; the parts where the heaps of surface mould were burned are most fertile; and manure even appears to be injurious, by causing the wheat to run chiefly to straw, with thin ears, and those of bad quality.

This extraordinary effect of torrefaction on the soil appears to me attributable to the combustion of those excrementitious matters, which are ejected by the roots of plants. When the soil is

impregnated with these matters, which are eminently injurious to vegetation, the perfect developement of plants is prevented. This excretion from the roots is evident from the surrounding earth, which becomes unctuous, and sometimes of a darker colour. In several of the euphorbiums and cicoraceous plants it is very perceptible, and milky. It may be observed too, that roots, when they multiply under water, become covered with a glairy matter, which deserves to be examined; and which no doubt the earth would have absorbed, had the roots remained buried in it. It is to these excretions from the roots perhaps we must frequently ascribe that kind of antipathy between certain plants, which are never found together. Thus the thistle is injurious to oats, euphorbium and scabious to flax, elecampane to carrots, fleabane and darnel to wheat, &c.

It would certainly be wrong, to ascribe the fertility of land pared and burned to the charcoal produced in this operation; for Mr. Chaptal has shown, that dry charcoal, alone or mixed with earths of little solubility, does not penetrate into the vessels of vegetables.

To add to the proofs, that vegetables have no need of drawing carbon from the earth, I might mention high trees, loaded with fruit, that grow and thrive on rocks or old walls, totally destitute of vegetable mould; and those vast forests, the soil of which is pure sand extending far beyond the roots.

I have now to examine the opinion, that vegetables absorb their carbon from the small quantity of carbonic acid contained in the atmosphere. Sennebier first announced this decomposition; and T. Saussure afterward endeavoured to prove, that this very small quantity would be sufficient for all the vegetables that exist. But though this philosopher was persuaded of the utility of carbonic acid in vegetation, he satisfied himself, that plants could grow in an atmosphere freed from it; and he ascribed this growth to the carbonic acid produced by the plants themselves, which they decomposed after having formed it.* To prove this he exposed to the sun closed receivers, in which plants were growing, and suspended quicklime to the upper part of them. The plants soon grew yellow, and at the expiration of five days

* It is obvious, that the carbonic acid formed by the plants could not furnish them with more of its base than it had previously taken from them. *Tr.*

gave no signs of vegetation; whence he inferred, that the absorption of carbonic acid by the lime was the cause of their death, and that the elaboration of this acid was necessary to vegetation in the sun. But I cannot be of his opinion. I have examined the experiment carefully, and satisfied myself, that the death of the plants was not owing to the privation of carbonic acid alone, but to the lime itself in vapour.

The following experiments convinced me of the volatility of lime.

1. Paper tinged by repeated immersion in infusion of litmus, then reddened, and afterward washed in water to remove its excess of acid, was suspended in a stopped phial, into which I had put with great caution some lime, that was slaked, and suitably moistened with water. It was not long oefore the red colour of the paper was changed to blue. This effect was not unknown to Fourcroy.

2. Into a retort I put with all possible precaution a certain quantity of lime and water, and by distillation I obtained a liquor impregnated with an intolerable smell of lime. This liquor left a disagreeable impression on the palate, and had manifestly alkaline properties.

Alcohol by its volatility carries up in vapour a much larger quantity of lime, as appears from an experiment of Proust. In order to obtain spirit free from acetic acid, he distilled 25lbs. of red wine with a handful of quicklime. The product was so much impregnated with the taste and smell of the lime, that he was surprised. When redistilled it had the same taste, precipitated metallic solutions and oxalic acid, and restored the blue of litmus.

Lime is not the only fixed alkali, that shows a disposition to rise at a pretty low temperature.

A solution of potash, subjected to distillation, afforded me a water with a strong lixivial smell. This water redistilled retained the same smell, and gave with nitrate of lead a white flocculent precipitate, which was completely soluble in distilled vinegar.

But there are other substances besides alkalies, the volatility of which is so little apparent in the temperature of the atmosphere, that it is discoverable only from its effects on organized beings.

Some Dutch chemists set plants in water, by the side of which they placed a small bottle of mercury, and covered the whole with a jar standing in water. On the third day the plants were co-

vered with black spots, and on the fourth, the fifth, or at latest the sixth, they were entirely black. The effects were the same when the jar rested on pieces of cork on a table. Other plants lived a long time under similar circumstances except the presence of mercury.

Sennebier and Hubert too have shown, that the vapour of sulphuric ether prevents germination from taking place, without altering the quantity of the air. Camphor, oil of turpentine, assafetida, vinegar, ammonia, bodies in a state of putrefaction, &c., have the same effect. Hence we may infer, that all those matters, which are injurious to animals, sensibly affect vegetables likewise.

We cannot therefore lay much stress on Saussure's experiments to show the utility of carbonic acid in vegetation, particularly when we recollect an experiment of Priestley's, which proved that an atmosphere with an eighth part of carbonic acid was sufficient to kill two plants of mint, though this small quantity of acid was in contact with a large surface of water.

Having found by experiment, that seeds germinate very well in oxydes of lead, which are known to be greedy of carbonic acid, I conceived, that these might contribute to elucidate the question respecting the utility of carbonic acid in vegetation. In consequence I moistened with distilled water some recently prepared oxyde of lead in the first stage of oxydation. This mixture I introduced speedily into a flint glass bottle : and though the disagreeable and as it were alkaline smell that arose from it, led me to doubt the success of my experiment, I sowed some mustard seed in this oxyde, and corked the bottle tight. As I foresaw, no germination took place : but what I was far from expecting, and to my great surprise, part of the oxyde of lead in the water was reduced by the seeds, each of which was enveloped by a shining coat of metallic lead. This appeared to me to be very probably owing to a production of water by the union of the oxygen of the oxyde with the large quantity of hydrogen, that is condensed in this oily seed, which after the reduction was more or less carbonized.

If the oxyd of lead be left exposed to the air for some time after it is made, and then put into a bottle with water and seeds, no reduction of the metal will be effected, but germination will take place.

(*To be Continued*)

SUGAR FROM STARCH.

The interesting experiments of M. Kirchoff, of St. Petersburgh, proving that starch may be converted into sugar by the action of diluted sulphuric acid, have been eagerly repeated by the most distinguished chemical philosophers in Europe. This singular conversion is produced by boiling 100 parts of starch with 400 of water, and from two to eight parts of strong sulphuric acid, in an unglazed earthen vessel, for a period of from 24 to 36 hours, constantly stirring the mixture during the first hour, (after which it becomes more fluid) and carefully maintaining the original quantity of water by adding more as it is wasted. Upon growing cold the mixture must be neutralized with chalk, and clarified by charcoal; filtrated through flannel, and evaporated to the consistence of oil. It must then be again cooled, in order to remove its sulphate of lime, and the clear liquor, if further gently evaporated, will yield about 100 parts of gummy syrup of the specific gravity of 1,295, easily susceptible of vinous fermentation, and when separated from the gum, which in general forms no less than a fifth part of it, capable of being crystallized, and applied to all the common purposes of native sugar. With the rationale of this very important transmutation we are not yet acquainted. It is plain, however, that the acid still exists undecomposed, and there is reason to believe that the quantity of water is increased. The probability therefore is, that the agency of the acid is exerted in abstracting from the starch a part of its hydrogen and oxygen, in the proportions requisite to form the excess of water, and in thus enabling its remaining principles to be in such a way arranged as to induce the extraordinary change effected.

COOKERY.

TO THE EDITOR OF THE EMPORIUM.

My good Friend,

YOU are about publishing a periodical work, which to please the class of readers likely to purchase it, must be, in great part, not so much an instructive, as entertaining compilation. It must be light, superficial, miscellaneous, desultory, full of well executed

plates, well printed, and so forth. Now if I know you well, (and I think I do) you will stuff it full of matter of fact; condensed, and screwed, and pressed, and packed into as small a compass as possible; containing as much solid meat for the mind as a hard stuffed Bologna sausage for the body; and almost as indigestible to the generality of readers. You will be apt to forget the wholesome advice of Horace, *omne tulit punctum, qui miscuit utile dulci.* You will make the useful useless, by neglecting the agreeable. You are anxious to instruct your readers; if you succeed you will do well: try to amuse them; if you succeed you will do better. Remember, when we leave school, we seldom allow any thing but the bottle, to *pang us fu' o' knowledge.*

I have thought of this: and as you well know that I most sincerely wish success to you and to your undertaking, I will, with your permission, tax my brains once every now and then, to give you aid in *my* way.

You have somewhere extolled the great importance of the ART OF COOKERY, which I regard as the first in importance among our *domestic manufactures:* and I therefore presume, that you will not object to a little theoretical, and a little practical knowledge being occasionally offered to the palates of your readers, on a subject that I am strongly inclined to think, both they and you hold in higher estimation than either of you choose to confess.

If you allow me a few pages of your Emporium for this purpose, I shall follow the advice I have given to you, and serve up my courses in a very desultory way; sometimes learnedly disserting on the history of this manufacture, sometimes treating it philosophically and chemically, sometimes popularly, and sometimes with practical recipes for the poor as well as the rich; for the art of cookery

Æquè pauperibus prodest locupletibus æquè

and presides as scientifically over the processes of the benevolent soup shops of England, as over the matelots of Paris, or the calipash and calipee of the West Indies.

Nor is the next line of the poet less true

Æquè neglectum pueris senibusque nocebit.

that is, a bad cook is the worst of plagues both to old and young.

But Cookery, as you well know, is not only a chemical manufacture in every part of it, but I shall take occasion hereafter to show, that much statistical knowledge, and many abstruse questions in

political economy, and even in tactics, are connected with and dependent upon the science of cookery; so that I shall gratify you greatly some time or other, by the depth of my researches on this subject; and you will not have to tax me with converting your Emporium into an *Almanac des Gourmands*. I would not say it for the world unless to yourself, but I greatly fear, my good friend, you will not make the Emporium either so pleasant or so popular, as that very lively publication. Some of your grave sober people may be shocked at such an attempt, and think it beneath the dignity of a serious work to entertain such disquisitions; but that man has lived to little purpose in the world, who does not know, that, for the most part, the high road to the heart is through the stomach. Look at the practice of the old country—Where is the business of the nation transacted? In the house of Lords, or of Commons? No: but at Cabinet-dinners. Can any patriotic measure be adopted that is not ushered in by a public entertainment? Does not the tide of public virtue flow strong in proportion to the oceans of port the company pour down? And with us, how quickly do we swallow the *sober* 16th bumper to the American fair, that we may shine out in patriotic volunteers? Look at all your charitable corporations—do the governors and directors of your hospitals and infirmaries in and about London, ever attempt a public subscription but at a dinner-meeting of the subscribers and their friends? It is true, the dinner is usually ushered in with a charity sermon by some dignified church-man, and voluntary with a presto movement, by some noted organist, but the contemplation of what is to come, the picture of the table in the mind's eye for an hour before hand, is an excellent stimulus, not only to the appetite for food, but the disposition for charity: nor does the reverend Dignitary ever refuse to grace the good things provided on such a laudable occasion. And this is right.

For my own part, I profess myself in direct opposition to all the principles and practices of anchorites and ascetics. I hold, that all wilful contempt and neglect of the bounties of nature—all obstinate refusal of gratifications that can be safely, conveniently, and innocently enjoyed, has in it something approaching to a sin of omission: it is a proud rejection of the means of happiness offered to us by the Creator of the universe; especially as the chearful use without abuse, even of convivial pleasure, has been repeatedly sanctioned by authority, which it suffices barely to hint at with becoming reverence.

When I hear a man say, "I never care what I eat or drink," I set down the remark, either as proof of affectation not founded in truth—or of sordid and miserly attention to worldly gain, that improperly absorbs all the thoughts—or of gross ignorance and incivilization. Why has the benevolence which framed our system, set before us, choice without end, but for the purpose of enabling us to choose? and the power of encreasing the zest of every pleasure, but that we may exercise it? Such a man may be a fit companion for the St. Simeons and St. Anthony's of former times, for a Hottentot or a new Zealander, a miser or a misanthrope of modern days, but he is not exactly fitted for good society in any sense of the word. I know of *no use whatever* attendant upon civilization, but the means it affords, and the skill it confers, of multiplying all our enjoyments, and indefinitely encreasing their powers of exciting pleasurable sensations. In my humble opinion, all happiness depends upon our wants and desires; the more numerous are these sources of gratification when they can be gratified, the happier the being. A stone has no wants and therefore no pleasures; a brute has few, a man in a state of nature more, but the wants of civilized, cultivated man, are innumerable. They are permitted to arise for the very purpose of promoting our happiness; they are the rewards of social improvement; and the human creature who neglects any pleasure within his reach, which he can *innocently* and *prudently* partake of, or sullenly refuse to cherish every want that his situation in life permits him *innocently* and *prudently* to gratify, is in my mind worse than unwise.

With respect to cookery in particular, I should be glad to know, whether that science whose aid we require twice or thrice in every day of our lives,—that science which teaches us to give sapidity to insipid substances—to heighten the flavour and encrease the nutritious power of food—to prevent the innumerable evils of indigestion arising from ill prepared nutriment—that science, which promotes the savings and encreases the enjoyments of the poor—which contributes to comfort, by inculcating cleanliness and economy—which banishes waste and therefore want—which gives habitual feelings of cheerfulness and good humor, by making every social repast equally wholesome and pleasant—and diffuses the light of practical philosophy among the lowest classes of society—I should be glad to know, I say, why such a science, is not as well worth pursuing, and as important to the world, as one that teaches us to give a brighter tint to a ribband, a clearer hue to the varnish of a tea-board, or a higher polish to a pair of scissars.

I am not concerned about the gloomy theories of Malthus, who has contrived to spread out through the heavy pages of a bulky quarto, but one, single, long-told, well-known truth, that "population is regulated by the means of subsistence, and that ex-"cess is usually counteracted by vice, war, pestilence or famine." I acknowledge that population depends upon subsistence, and therefore I assert, that next to agriculture which provides the raw material of food, Cookery among the arts, ranks highest in importance. For it teaches us so to manufacture the raw material, as to make it more economical, more grateful, more nutritious, and more digestible. I hope hereafter to explain the reason, why it is, that where Frenchman would live luxuriously, an Englishman or an American would starve. Swift said, that the man who should make two blades of grass grow, where one grew before, would rank among the greatest benefactors of mankind: nor is he less so, who can make that quantity of food nourish two people, that was heretofore consumed by one.

Neither do I believe in the old adage, *plus occidit gula quam gladius;* the appetite kills more than the sword: and if it were true, I would certainly rather die of turtle soup, than a *Coup de Sabre*, if it were left to me to determine the mode of exit. For my own part, I scruple not to acknowledge the wisdom of the poet's advice,

> Let sages pretend to despise
> The joys they want senses to taste:
> But let us, seize old time as he flies,
> And the blessings of life while they last.

To all this I would add no restraint but the two maxims which regulate my theory: *use without abusing: cherish no want, that prudence forbids you to gratify.*

But that I may begin in regular order, I must follow the example of other scientific men; and as you chemists explain to your students in the outset of your lectures, the terms of art you propose to employ, such as solution, saturation, precipitation, distillation, sublimation, volatilization, condensation, effervescence, efflorescence, oxygen, hydrogen, &c. &c. I must explain the terms of art in my science also. Chemists, like the Romans of old, draw upon the Greek Language: every word, is legitimate *si græco fonte cadat:* the French, is *our* Greek Language; and their writers our classics on the subjects in question. I am not a thorough Frenchman, but we may be allowed to acquire knowledge wherever we can get at it; *fas est et ab hoste doceri.* You must for-

give these scraps of Latin: "Tis my vocation Hal," as Falstaff observed; Cooks, you know, are professionally addicted, to *interlarding*.

I begin then, with an explanation of technical terms. And I must observe, that much as the knowledge of women is undervalued, I do not believe that one half of the chemists in Europe, either pay so much attention to the theory of their science, or superintend so many, and such a variety of important and complicated experiments, as we require in general from well educated women. They are expected as a common accomplishment, to direct with elegance and economy the appointment of the table; and to do the honours of the entertainment, not only with easy dignity, but in so doing, to recommend with science and with skill, the various dishes that may tempt the indulgence of appetite, and promote the pleasures of the repast.

I give the following table of explanations, because those great men, the lexicographers, the compilers of Encyclopædias, and circles of sciences, think themselves above the contemptible science of Cookery, and give us neither knowledge of the art, or explanation of the terms. Although these wiseacres of literature, were in my time, by no means averse to Mr. Dilly's dinners.

But the really great men and wise men of the world, have been, not gluttons and gormandizers, like Apicius or Heliogabalus, but Epicures; whose pleasures were enjoyed when they had leisure for pleasure, with discrimination, elegance and taste. Indeed, what is taste, in its original signification, but the science of eating? so of cheerfulness, what is it but the habitual good humour of a man accustomed to indulge in good cheer—cheer-full?

Alcibiades and Pericles were Epicures: so was Lucullus: so was Julius Cæsar: so was Augustus: and Mecenas. So was old Fritz of Prussia: and so is Buonaparte; who has directed his chief pharmacist M. Cadet to institute and publish a series of experiments on the best mode of making Coffee, and who has sanctioned the receipts of M. Appert, on the art of preserving viands by exposing them to heat in close vessels.

No man who has seen the busy, good humoured complacency with which Mr. Fox used to tuck his napkin into the second button hole of his waistcoat on sitting down to table——or who has cast his eye on Mr. Pitt's plate and Mr. Pitt's bottle at Grocer's hall ——or who has perused the facetious sarcasms of brother Peter on Mr. Percival's soup and claret——can pretend that the dull compilers of Dictionaries and Encyclopædias, have a right to turn

up their noses at the description of a good dish or a good dinner. That right courteous and accomplished Knight, Sir Kenelm Digby, seems to have furnished from his own collection, most of the receipts, that Howard his cook afterward published: one of the best books of cookery extant, we owe to Sir John Hill; and your colossus of literature Dr. Johnson, was notoriously enchanted with the charms of a well appointed table.

Supported by the practice and opinions of so many warriors and sages, have I not a right to say that the subject is not beneath the dignity even of your Emporium? and that your Honour may now and then without derogation from the dignity of a professor's chair, accept of my mite thrown into your treasury of knowledge?

Enough of apology; and now to business. The following vocabulary will enable your readers to understand in some degree, the technical phrases of the French kitchen, not easily attained elsewhere. The French cookery certainly unites the following qualities: 1st It possesses more artificial flavour: 2ly It dissipates less, the natural flavour of meat: 3ly It does not waste the meat itself: 4ly It renders food more digestible and nutritious: 5ly It combines a more wholesome and judicious mixture of animal and vegetable food: 6ly It economises fuel: and 7ly It is not so laborious, or so hurtful to the eye sight, as the English or American practice. All these points, I will some time or other, endeavour to illustrate.

Terms used in French and English Cookery.

A

Aspic: any sharp fragrant sauce.

Aloyau: sirloin of beef.

Ail-poireau: Spanish garlic. Allio-prasum scorodoprasum, Rocambole.

Ail: common garlic; allium sativum. Gousse d'ail, clove of garlic.

Andouilles: chitterlings.

B

Bouillie: beef long, and slowly, stewed till quite tender.

Bouillon: broth.

Baignets: Fritters.

Ballon: round like a ball.

Barder: to cover fowl or veal with thin slices of bacon.

Bagatélles: thin slices of seasoned meat rolled up like a sausage, tied and stewed.

Becasines: snipes.

Bechamel: white cullis, white sauce or gravy.

Blanquet: a hash-fricassèe of white meat.

Blanch: to whiten, for which purpose, to scald (as almonds): to soak in water (as fresh meat), &c.

Blanc-mangè: Blamange: white food: usually milk thickened with isinglass, sweetened, spiced, flavoured, and sometimes coloured, as Jaune mangè.

Brill: a kind of turbot.

Braze: } to stew gently over a charcoal fire.
A la braise: }

Breche: the spit.

Bresolles: collops.

C

Catch, catching: to adhere to the bottom of a pan.

Calves-cauldron: calves tripe or chitterlings.

Caramel: glazing.

Cardoons: a kind of artichoke.

Canelon: gun-shaped: sausage-shaped.

Canè de veau: neck of veal.

Crepinette de Gordeveau: veal fried with forcemeat.

Cuisseau næud: knuckle of veal.

Chibbol: small onions.

Champignons: small mushrooms.

Consommè: strong, clear, jelly-broth.

Court bouillon: stewed with wine and sweet herbs.

Cullis: Coulis: an extract of meat, flavoured, seasoned, and strained; to be kept in reserve, to give strength and flavour to other dishes of the same kind of meat.

Consommè: a strong, clear, jelly broth.

Court bouillon; stewed with wine and sweet herbs.

Cervellas: sausages.

Collotte: a rump of beef.

Compote: any thing stewed, with turnips, carrots, and small mushrooms.

Chowder: a New England dish, consisting of fish cut in pieces, seasoned, and stewed with alternate layers of sea-biscuit and fried bacon; in a covered pot with parsley, and onions.

Culotte: a saddle, as of venison or mutton: the rump.

Coul or caul: the fat membrane, that covers the outside of the intestines.

Corkants; ornamental paste.

Cotelettes: cutlets; properly, the small ribs.

Confitures: preserves; sweet meats.

D

Daub or dobe: meat larded with lardons, or thin slips of gammon or bacon.

Darde: a large slice of fish cut lengthways.

E

Entrèe: a course of dishes, with Sauces, Patisserie and Laitage;

Entremets: small plates of sallad, omelets, &c. placed between the main dishes. It was anciently used for the amusements that intervened between the courses at a grand entertainment.

Eschalots: shalots.

Estragon: Terragon, for salads and vinegar; the vinegar de Maille, is an infusion of terragon and shalots. Terragon, is the Artimisia dracunculus.

Etuvèe, a l'etuvèe: stewed on a stove.

F

Four: a la four; baked.

Fricandeau: meat larded, brazed, and then glazed with a gravy caramel.

Fricassèe: stewed and thickened with a liaison, (which see.)

Filets: long slices, usually from the neck.

Flee: Hog's seam.

Farcie: forced meat.

Friture: the sauce in which any thing is fried.

Fritters: small pancakes: usually fruit, thinly sliced, dipped in batter, and fried.

Frites: fried.

Fumet: high flavoured game.

Frais: fresh.

Fraise de veau: Calve's caldron.

G

Grits: groats: shelled oats, or wheat, used in the north of England and in Scotland with meat.

Gras: fat meat.

Gratin: the concentrated brown gravy, or juice that adheres to the bottom of the pan.

Grenadins: small fricandeaus.

Girkins: small cucumbers for pickling.

Grillè: broiled.

Gigot: a leg.

Gateau: a meat cake.

H

Hors d'ouvres: small savoury dishes; Relishes, as anchoves, Sausages, Oysters, &c.

Harricot: meat half fried, and then stewed with herbs and roots. Kidney beans.

Haslets: liver, &c. of Hogs.

Hatereau: a haslet.

Haggis: a sheep's paunch stuffed with fowl, forcemeat, groats, onions, herbs, &c. much used in Scotland.

Jus. Gravy.

I

L

Laitage: dishes of which milk is the basis.

Liaison: any intermedium to make two substances mix, that would not mix otherwise, as an egg to oil and vinegar. Any thing used to thicken gravy, and make the gravy and the fat unite in an uniform mixture, as the yolk of eggs. The Liaison must never be put in the fluids while boiling.

Lazagne: an Italian paste.

Lard: Bacon proper for larding. Hog's fat clarified: often used in cookery instead of butter.

Lardoons: Lardons. Bacon cut in thin slices and inserted in the flesh of meat that requires juice or flavour. Long, small strips of fat bacon inserted in meat by means of a needle, called a larding needle.

Lentils: such vegetables as are contained in shells and husks, as pease, beans, &c. A small pulse, of a lenticular, or double convex shape.

Leveret: a young hare. In the northern parts of New York and Pennsylvania, they are some times found in the winter, white.

M

Macaroni: a sweet, very thin, tubular biscuit.

Matelot: a hotch pot, a sailor's dish: a very favourite French dish, made of carp and eels, cut in thick pieces, washed, seasoned with pepper, salt, and spice (either with or without sweet bread, oysters, or lobsters) and stewed with strong gravy, claret or red port, with trufles, morells, small onions and champignons, or button mushrooms.

Marinade: to soak in a pickle previous to dressing.

Marmalade: Jelly of the pulp of fruit.

Meagre: Soup Meagre: without flesh meat.

Mignionette cloth: a small bag.

Morelles: see Trufles.

N

Nosegay: a small bundle or faggot of sweet herbs; such as parsley, celery, chervil, thyme, marjoram, savory, rosemar, tarragon, Cay-leaf, &c. tied up with thread.

O

Omelettes: Pancakes of Eggs beat up, either alone, or with gammon shred fine, grated cheese, &c.

P

Plateau: the silver tray, or mirror that supports the ornaments and flowers in the middle of the table.

Pate: Pates. Paste. Patties.

Patisserie: Patties; Pastry.

Poupeton: a meat pudding.

Poivrade: a peppery sharp sauce.

Papillotes: broiled in paper.

Paupiettes: olives of meat.

Potage: soup.

Purèe: a strained soup; pease soup made with English or Albany pease well boiled in meat soup, and strained through a sieve, served with dried mint on the top. The pole-bean of this country answers tolerably well; but nothing is so good for the purpose as the English split pea.

Q

Quenelles: force-meat balls.

R

Restaurateur: the keeper of an eating house: one who professes to compose nourishing and restorative dishes.

Restaurant: a strong broth or cullis, made of meat, fowl, and game.

Ragout: any dish stewed with herbs and onions, high seasoned.

Reveil: to quicken the palate.

Rocambole: Spanish garlic, not quite so strong as the common garlic, but stronger than shallot.

Rissolles: } Browning. Any thing fried brown, as Collops
Rissollettes: } or force-meat.

Remoulade: mustard sauce, with horse radish and shalots.

Ravigotte: a piquant, relishing sauce.

Ramequins: cheese cakes.

Roumestèe: Jelly broth of fragments.

Rouelle: a small filet.

Rognon: kidney.

Rots: Roties: roast meat, fowl or game.

S

Stock: strong broth; coulis or cullis.

Semouille: an Italian paste.

Simmer: a heat much short of boiling.

Salpicon: a ragout, or a farcie of liver: stuffing.

Salmix: a hash made at table of meat half drest for the purpose; as venison, ducks, &c.

Salamelec: hotch pot.

Surprize: disguised meat; covered with force-meat.

Saucisses: Cervelas: sausages.

T

Traiteur: one who furnishes dinners at so much per head.

Tourte: a pie or tart; often of meat, fowl, or fish.

Tartlets: paste baked with preserves put on it.

Timbale: a mould.

Trufles: Morelles: Morilles: the trufle is the subterraneous Lycoperdon, about the size of a potatoe, found 3 or 4 inches under ground in clusters, and weighing from 2 to 4 ounces. It is used to give richness and flavour to sauces like the champignon or mushroom.

Morelles. Morills, are the agaric of decayed wood, having a thick fleshy curled cap, pierced with holes. They are used for the same purpose as mushrooms, and trufles; and all of them, whether fresh or dried, or in powder, are excellent additions giving fullness and sapidity to sauce.* V

Volailles: an entrè or course of wild or tame fowl.

* In this our soi-disant civilized Country, where the proper use of baths hot and cold is almost unkown—where we have neither hot walls, espaliers, or hot houses—where grapes which might and ought to be as plenty as currants, are scarce and dear—where apricots and nectarines, the finest of European fruits are hardly eatable—where the pine apples imported, instead of being grown here, are the refuse of the West India fields—where a good orange is *never* seen—where artichokes, and even cauliflowers and brocoli, are actually curiosities—where steam is unknown either as a medicinal bath, or to warm dwellings, to cook vituals, or to force hot house plants; and is but just known as a power to move machinery—where in our cities in summer, we are content to be stewed in brick ovens with the roofs off, called streets; and in our houses in winter, to expose our faces to be broiled, and our backs to be frozen—in this country, I say, we have no cultivated mushrooms, we have no trufles, we have no morells: even ketchup and anchovy liquor are almost unknown, and for soy, you may enquire in vain.

"Why then if you can't do without them, and dine upon on a plain dish, "you ought to starve."—

TO THE EDITOR.

SIR—A publication of the following curious calculations on weights and measures, &c. will probably gratify your scientific readers, and diffuse useful information to your subscribers in general.

—

WEIGHTS AND MEASURES, &c.

From a course of lectures on Natural Philosophy and the Mechanical Arts, by THOMAS YOUNG, M. D. 2 *vols.* 4*to.*—*London. Price* J5 5*s.*—*Johnston*, 1807.

The English yard is said to have been taken from the arm of king Henry I. in 1101.

Graham found the length of the pendulum vibrating seconds accurately, equal to 39-13 inches. *Desaguliers.*

Bird's parliamentary standard is considered as of the highest authority, it agrees sufficiently with sir George Shuckburgh's and professor Pictet's scales, made by Troughton.

The royal society's standard, by Graham, is perhaps about a thousandth part of an inch longer than Bird's; but it is not quite uniform throughout its length.—*Maskelyne Ph. Tr.*

The standard in the exchequer, is about ·0075 inch shorter than the yard of the royal society.—*Ph. Tr.* 1743.

General Roy, employed a scale of Sisson divided by Bird. He says it agrees exactly with the tower standard on the scale of the royal society.—*Ph. Tr.* 1785.

Taking Troughton's scale for the standard, sir G. Shuckburgh, finds the original tower standard 36.004; the yard E on the royal

An Esquimaux or a Laplander, with his dried fish and train oil, or a Border-Indian with his jerked venison and bear's fat, might with equal ignorance and stupidity, make a similar exclamation! I know of nothing so debasing, nothing so characteristically brutal, as the indiscriminate satisfying of mere animal appetite.

But let us consider: is there any thing which ought to be called knowledge, but what consists in the methods of alleviating pain, and producing, promoting, prolonging, and communicating grateful, pleasurable feelings? Is there any use whatever of riches, but as they contribute to the same good purpose? If this be true, then is that man a public benefactor, who in any manner improves the theory of pleasurable sensations. Who contibutes to promote cheerfulness by good cheer, and to cultivate TASTE, whether as applied in its literal, or its metaphorical meaning—whether to the pleasures of sentiment or the pleasures of sense. Adieu. *Epicuri de grege Porcus.*

society's scale by Graham, 36,0013 inches; the yard exchequer of the same scale, 35.96933; Roy's scale, 36.00036: the royal society's scale by Bird 35.99955: Bird's parliamentary standard of 1758, 36.00023.

The English standards are adjusted and employed at the temperature of 62° of Fahrenheit's thermometer; the French at the freezing point of water.

The French metre, the ten millionth part of the quadrant of the meridian, is 39,37100 English inches.—*Pictet and Journ: R. I.*

The metre has been found to contain 36.9413 French inches, or 3 feet 11.296 lines

Hence the French toise of 72 inches is equal to 76.736 English inches. One of Lalande's standards measured by D. Maskelyne, was 76.732; the other 76.736—*Ph. Tr.* 1765.

In latitude 45° a pendulum of the length of a metre would perform in a vacuum 861165 vibrations in a day. *Borda.* The length of the second pendulum is 993827 at Paris.—*M. inst*: 11.

Allowing the accuracy of the French measurements of the arc of the meridian, the whole circumference of the globe will be 24855,43 English miles; and its mean diameter 7911.731.—*Journ. R. In.*

A bushel of wheat, at a mean, weighs 60 pounds; of barley, 50; of oats, 38.

[It is settled law, that no sale in England is valid by any other bushel than the Winchester bushel: which by act of Ap. 1697, must be a cylinder with an even bottom 8 inches deep and 18½ diameter. This vessel will contain 2150,42 cubic inches.]

A chaldron of coals is 36 heaped bushels, weighing about 2938.

Ten yards of inch pipe contain exactly an ale-gallon, weighing 10 2-9th pounds.—*Emerson.*

The old standard wine gallon of Guildhall, contains 224 cubic inches.

By an act of queen Ann, the wine gallon is fixed at 231 cubic inches.

It is conjectured, that some centuries before the conquest, a cubic foot of water, weighing 1000 ounces, 32 cubic feet weighed 2000 pounds or a ton; that the same quantity was a ton of liquids, and a hogshead 8 cubic feet, or 13824 cubic inches, one sixty-third of which was 219,4 inches, or a gallon. A quarter of wheat was a quarter of a ton, weighing about 500 pounds and a bushel one eighth of this, equivalent to a cubic foot of water. A chaldron of coals was a ton; and weighed 2000 pounds.—*Barlow.*

TO THE EDITOR.

SIR—A publication of the following curious calculations on weights and measures, &c. will probably gratify your scientific readers, and diffuse useful information to your subscribers in general.

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WEIGHTS AND MEASURES, &c.

From a course of lectures on Natural Philosophy and the Mechanical Arts, by THOMAS YOUNG, M. D. 2 *vols.* 4*to.*—*London. Price* J5 5*s.*—*Johnston*, 1807.

The English yard is said to have been taken from the arm of king Henry I. in 1101.

Graham found the length of the pendulum vibrating seconds accurately, equal to 39-13 inches. *Desaguliers.*

Bird's parliamentary standard is considered as of the highest authority, it agrees sufficiently with sir George Shuckburgh's and professor Pictet's scales, made by Troughton.

The royal society's standard, by Graham, is perhaps about a thousandth part of an inch longer than Bird's; but it is not quite uniform throughout its length.—*Maskelyne Ph. Tr.*

The standard in the exchequer, is about ·0075 inch shorter than the yard of the royal society.—*Ph. Tr.* 1743.

General Roy, employed a scale of Sisson divided by Bird. He says it agrees exactly with the tower standard on the scale of the royal society.—*Ph. Tr.* 1785.

Taking Troughton's scale for the standard, sir G. Shuckburgh, finds the original tower standard 36.004; the yard E on the royal

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At present, 12 wine gallons of distilled water weigh exactly 100 pounds avoirdupois.

A hundred English wine gallons of common air weigh a pound avoirdupois.

On the subject of labor of workmen, Dr. Young observes:

In order to compare the different estimates of the true force of moving powers, it will be convenient to take a unit, which may be considered as the mean effect of the labor of an active man, working, to the greatest possible advantage and without impediment; this will be found, upon a moderate estimation, sufficient to raise 10 pounds, 10 feet in a second for 10 hours in a day: or to raise 100 pounds, which is the weight of 12 wine gallons of water, 1 foot in a second.

For every minute that a clock varies in a day, a second pendulum must be altered 2-37 or .054 inch. A half second pendulum 1·74 or .00134.

Rain and Dew.—Dalton makes the mean for England and Wales 36 inches amounting in a year to 28. cubic miles of water, that is 7-12, and thinks that the Thames carries off 1-25 of the rain and dew that falls in England; other rivers 8 times as much, making together 13. inches and leaving 23. for evaporation.

MAGNESIAN LIMESTONE.

Some time ago the honourable *Richard Peters*, of Belmont, near Philadelphia, requested I would take the trouble of analysing some limestones for the purpose of ascertaining the quantity of magnesia they might contain. In England, the impression among scientific men, in consequence of the experiments of Mr. Tenant, in Phil. Trans. 1790, are, that limestone containing a considerable quantity of magnesia, such as the limestone of York, in Yorkshire; Bredon, in Leicestershire; Matlock, in Derbyshire, and some other places, were unfavourable to agriculture. Mr. Tenant found that seeds sown in earth, sprinkled with lime made from calcareous limestone, vegetated very well, and the lime operated favourably: but when sprinkled with an equal quantity of lime, made from a stone that contained two parts of magnesia to three of pure lime, they did not vegetate.

His experiments were made, evidently on *secondary* limestones containing magnesia; and the stratum of this kind of limestone he found superincumbent on the purer calcareous stone; and which in general he considers as alluvial limestone, in reference to the strata on which his experiments were made.

Judge Peters transmitted to me, nine different specimens of limestone from Chester county, numbered and named as follows:

No. 1 Holstein.	No. 5 Hughes's.
2 Coates's.	6 Dr. Gardener's
3 Yocum.	7 Barnet's,
4 Cleaver's.	8 Ballee's.
	9 Baker's.

Of these No. 7 is regarded as the strongest for building or for land, and No. 9 the weakest. The first four are strong lime, 5 and 6 of medium quality, and No. 8 nearly equal to No. 7: that is, according to their reputation in the neighbourhood.

Upon these limestones I have made experiments for the purpose of ascertaining their component parts, but chiefly as to the magnesian earth, they may hold.

It is not an easy problem to discover the most simple, the cheapest, and the most accurate method of separating magnesia from limestone and clay, (from lime and alumina.)

We have no good precipitant of magnesia: phosphoric acid requires combinations that make the results complicated, and drive us to calculation, which when I can, I would avoid.

The following methods have been used, to separate magnesia from a combined solution of lime and magnesia in the muriatic acid.

1st. Separate the lime by the oxalic acid. This is too expensive.

2ly. Precipitate the lime by saturated carbonat of potash, which in the cold throws down the carbonat of lime, and the residual liquor heated lets fall the carbonat of magnesia. This is a method recommended by Davy and Henry; but I have never been able by this method perfectly to keep separate the carbonats of these two earths.

3ly. Throw down the carbonat of lime by carbonat of ammonia: filter: then add to the muriat of magnesia containing carbonat of ammonia, phosphat of soda. The ammoniaco-phosphat of magnesia is precipitated; and 151 grains of this triple sult dried at 90° of Fahrenheit, answers to 100 grains of muriat of magnesia. Hence, if 20 grains of a mixed solution of the muriats of lime and

magnesia give 15,1 grains of ammoniaco-phosphat of magnesia, the mixture contains equal quantities of muriat of lime and magnesia. Or, 100 grains so dried are equal to 111 grains chrystallized, or 62,2 of dried sulphat of magnesia. But this seems to me below the average water of chrystallization in sulphat of magnesia, which contains nearly 50 per cent. 26 Nich. Journ. 274.

This process, is used by Dr. Henry, Dr. Wollaston, and I believe by Dr. Marcet.

4ly. The lime may be precipitated by oxalat of potash, and the muriat of magnesia, may be separated either by the filter or by alcohol: and precipitated either by hot carbonat of potash, or by ammoniaco-phosphat of soda. Or the alcohol or the acid may be driven off by exposure for an hour to red heat. Or, by sulphuric acid, the magnesia may be chrystallized under gentle evaporation into Epsom, or the bitter purging salt of magnesia.

5ly. The muriat of lime, may be precipitated into Gypsum, either by sulphuric acid, or by Glauber's or Epsom salt acidulated with a few drops of oil of vitriol.

6ly. The limestone containing magnesia, may be reduced into an impalpable powder, and treated with an equal weight of oil of vitriol, mixed with thrice its quantity of water. When the limestone is well powdered and sifted through fine muslin, and the superfluous acid driven off by heat, I believe this is as good a method as any.

In making the experiments of which I am about to give the result, I proceeded in two ways.

First. I took 100 grains of the stone powdered and sifted, and treated it with muriatic acid diluted with three waters by measure, stirring it frequently: after four hours, the supernatant liquor was poured off, and the undissolved residuum washed with an equal quantity of hot water as of the acid liquor, filtered, and dried in the heat of bout 160 Fah. and then weighed.

The solution, was then precipitated by a sufficient quantity of oil of vitriol cautiously added: it was left to stand after stirring till the gypsum had formed. Then filtered, and the separated gypsum put aside.

This second filtered solution, contained, muriat of magnesia, a small quantity of sulphat of magnesia, a small quantity of sulphat of lime, and alumina, with excess of acid. The alumina was thrown down in a dirty-coloured floculent precipitate, by the caution addition of carbonat of ammonia, and was separated by the

filter and washed, dried and weighed. The solution was then precipitated by hot carbonat of potash which threw down the magnesia and the lime; and filtered. This precipitate was re-dissolved in sulphuric acid, and left to stand. The sulphat of lime (generally about one sixth) separated spontaneously, fell down and was added to the first portion.

The whole of the magnesia was then thrown down by carbonat of potash, well washed, dried over a charcoal fire in the heat of about 160° and then weighed.

The sulphat of lime, or gypsum, was exposed in a crucible for 2 hours to a red heat, and the lime calculated on the proportion of 100 parts limestone to 130 of the anhydrous gypsum. A proportion, for which I will assign my reasons in a supplement to the present paper.

Secondly. I proceeded in another way.

I treated the finely powdered limestone with strong sulphuric acid (oil of vitriol of commerce); triturating them together in a glass mortar. I then added four times the quantity of water. The clear liquor was decanted from the sediment which was washed with another portion of water, and the liquors added together. The sediment (gypsum) was rendered anhydrous by exposure to a red heat in a crucible for 2 hours, and the limestone calculated on the proportion of 10 parts limestone to 13 of anhydrous gyps: deducting the silex previously found. The filtered solution to which the washings were added, was concentrated by evaporation, which occasioned a slight precipitate (about $\frac{1}{6}$th) of sulphat of lime: it was then treated with carbonat of ammonia for the alumina, and with carbonat of potash for the magnesia as before.

The component parts of the stones sent to me, were ascertained on the average of these two methods.

The limestones transmitted to me, bore evident marks of contiguity to primitive strata. The colouring matter was black hornblende, sometimes in streaks or veins, sometimes minutely divided and mixed with the limestone, giving the greyish tinge to the stone. The 9th specimen was intermixed with mica; the insoluble residuum of the four first specimens in dilute marine acid contained a small portion of matter, silky to the touch. I believe all the limestones connected with the range of primitive formations on the seaboard of our country from Boston to Virginia contain more or less of magnesia. They are in the immediate neighbourhood of the steatite and other magnesian strata, that envelope as a matrix, the

chromat of iron. I tried the specific gravity of three of them, which varied from 2,65 to 2,72 the usual range of common limestones.

No. 1. *Holstein :* Colour, greyish white : Fracture, uneven : Surface, common splintery : the stone seems to consist of minute lustrous chrystals : slightly fetid on being pounded. I obtained in 100 parts, silex 3, alumina 2, carbonat of magnesia 12. The rest was carbonat of lime or pure limestone. The traces of iron were evident with tincture of galls and prussiat of potash, but in no greater degree than might be attributed to the usual impurity of the acids of commerce. My muriatic acid was freed from the sulphuric, by muriat of Baryt.

No. 2. *Coates's.* Colour, greyish white : Fracture, uneven : Surface, fine splintery, consisting of minute sparkling chrystals. I obtained in 100 parts, of silex 3, alumina 2, carbonat of magnesia 14. The rest was pure limestone.

No. 3. *Yocum's.* Colour, greyish white streaked with blueish grey, being coloured with hornblende (amphibole.) Fracture uneven : Surface, splintery, small sparkling chrystals. I obtained in 100 parts, silex 4, alumina 2, carbonat of magnesia 14. The rest was pure limestone.

No. 4. *Cleaver's.* Colour, blueish grey : Fracture uneven in one direction, but splitting into laminæ of about ¼ an inch thick in the other ; there was a very thin clay coloured sediment between the luminæ : Surface, opake, without lustre. I obtained from 100 parts, silex 4, alumina 6, carbonat of magnesia 14. The rest was pure limestone.

No. 5. *Hughes's.* Colour, white inclining to grey : Fracture uneven : Surface splintery, opake, void of lustre. I obtained from 100 parts, silex 5, alumina 2, carbonat of magnesia 12. The rest, pure limestone.

No. 6. *Dr. Gardener's.* Colour greyish, inclining to blueish white. Fracture uneven : Texture, a very fine, easily-pounded, sandy grit, consisting of minute lustry chrystals. I obtained from 100 parts, silex 2, alumina 0, carbonat of magnesia 16. The rest, pure limestone.

No. 7. *Barnet's.* Colour, white with a very slight clay coloured tinge : Fracture uneven : Surface, chrystallized lustry facets : Texture, saccharoid, the same as the saccharoid limestone on the York turnpike road about 10 miles from Baltimore. I obtained, silex 1, alumina 0, carbonat of magnesia 14. The rest, pure limestone.

No. 8. *Buller's.* Appearance like No. 7, only the facets of the chrystals much smaller. Silex 1, alumina 0, carbonat of magnesia 14, the rest limestone.

No. 9. *Baker's.* Colour ash-grey intermixed with brown mica, so as to bear the appearance of a mixture of pepper and salt: Small lustry chrystals. I obtained silex 36, undecomposed mica 4, alumina by precipitation 6, carbonat of magnesia 4. The rest limestone.

Hence it should seem, that the proportion of magnesia in these stones, is not so great as to produce any remarkable effect, either in agriculture, or as cements. The last (No. 9,) is doubtless the worst, as containing so large a proportion of siliceous sand, which on light soils is worse than useless.

Tenant's limestones, contained a much larger portion of magnesia, and the effect was therefore more evident. The greater proportion of limestone used in England than in this country, with the same effect, may arise not from the nature of the lime, but of the soil whereon it is put. It is there used in large proportion to strong loamy arable soils, and to swampy, spouty ground, that tends to produce sorrel. When it is used for the purpose of producing white clover, for which it seems to be a specific stimulus, it is not applied in greater proportion there than here, and merely as a top dressing. That is, so far as my observation and recollection enables me to speak on the subject. T. C.

On Sulphat of Lime, Plaister of Paris, or Gypsum, and the methods of ascertaining it.

There are two natural varieties of sulphat of lime, the common or *hydrous;* and the *anhydrous* containing no water of chrystallization.

The common plaister of Paris is made anhydrous by boiling from 4 to 6 hours in an iron pot: and it becomes a *cement*, by re-absorbing its water of chrystallization.

Common sulphat of lime, may be made anhydrous, by exposing it in a crucible in small quantities to a full red heat for an hour.

The carbonic acid in common limestone may be regarded as 44½ per cent.

Smithson Tenant obtained 39 grains of calcined sulphat of lime by means of vitriolic acid, from 30 grains of carbonat of lime. This agrees with my own observation from repeated experiment.

Vauquelin, Berthier, and Thompson, compute the lime in calcined sulphat of lime at 42 per cent. Klaproth and Henry at 41 per cent. Chevenix 56,3 per cent.

Hence, according to Tenant, 77 parts of limestone will make 100 parts of *calcined gypsum.*

According to Vauquelin, Berthier, and Thompson, it will require 75,67 parts of limestone.

According to Klaproth and Henry, 73,87 parts of limestone will suffice for 100 of gypsum.

According to Chevenix it will require 101,4 parts of limestone. (2 Nich. Jour. 196.)

Hence also, taking the average of the experiments of Vauquelin, Berthier, Thompson, Klaproth and Henry, and considering the lime to be 41½ per cent. in anhydrous gyps, 100 grains of limestone ought to produce 135 grains of sulphat of lime; which according to Henry, 26 Nich. Journ. 278, it does produce at a low red heat.

Bucholz and Thompson make the common gyps to contain 24 per cent. of water of chrystallization: Bergman and Henry 22: taking 23 as the average, then the analysis of common gyps will be acid 44: lime 33: water 23 per cent. For my own part I never could expel more than 21½ parts of water, from 100 parts of gypsum.

The experiment of Mr. Chevenix cannot be reconciled with any of the rest.

Hence it is manifest that there is no accurate agreement among Chemists, either as to the proportion of lime in gypsum, or the proportion of water in that substance. This diversity is owing entirely to the varieties of temperature in which the gypsum when obtained by their experiments was dried.

On entering on the course of experiments to ascertain the component parts of the limestones sent to me by judge Peters, I found it convenient to institute a set of experiments on gypsum for myself.

Klaproth from 100 grains of pure carbonat of lime, procured 160 grains of chrystallized gypsum.

Henry and others at a low red heat procured 135 grains.

Tenant at a higher heat 130 grains.

I procured 150 grains of gypsum from 100 of pure limestone, when the gypsum after being carefully washed in a moderate proportion of water was dried for an hour on the top of a ten plate stove, on which I could just bear my hand. But when I calcined it for an hour in a full red heat, I procured from 100 grains of carbonat of lime, but 130 grains of gypsum.

I took a well characterized piece of compact gypsum from a ton that lay for sale in the street here; and reducing it to fine powder, I calcined it in a crucible in a *full* red heat for an hour. I drove off 21½ parts: this occurred to me three times.

I took from a lump of the same gypsum (Nova Scotia, imported to Baltimore and thence sent to Carlisle) some of the semi-transparent chrystals of a vein that ran through the lump. Exposed to heat in the same manner, the result was the same.

Hence I conclude; that 100 parts of pure carbonat of lime, will yield 130 parts of anhydrous gypsum (from which the water has been expelled) and from 151 to 152 parts of gypsum as it is commonly found.

In the spring of 1809, I went into the Genesee country, and brought with me to Northumberland several specimens of gypsum which I had found there. I have since understood that Mr. Church of Angelica in that country, had previously discovered and used some gypsum, as a stucco.

The country adjoining the waters of the north east branch of Susquehanna, are now supplied with gypsum from the Genesee. This commerce began in 1811. A set of people in the neighbourhood of Pine creek in 1812, sold great quantities of common limestone for gypsum, and deceived many farmers, and injured many millstones by the deception. It may be worth while to give a few *characters of gypsum* that may prevent a similar imposition.

First. When a piece of stone is presented to you as gypsum, try to scratch it with your nail, and to chew it between your teeth. You may thus scratch and pulverize gypsum, but you cannot easily do so with limestone, which is much harder.

Secondly. Drop on it, a drop of spirit of salt, or of aqua fortis. If an effervescence, a bubbling, and extrication of air ensue, the stone is probably limestone; for no such effervescence takes place on a piece of gypsum, but the acid spreads evenly upon the surface as a drop of water would do. Now and then indeed, a specimen of gypsum may contain a small portion of limestone, but this does not occur often.

Thirdly. If the preceding tests do not give satisfaction, then take 100 grains of the stone: reduce it to a fine powder: grind up with it 250 grains of common pearl ash, boil them in a tin or earthen vessel with half a pint of water to dryness. Wash what remains by three separate affusions of half a pint of boiling water: dry the sediment at the bottom. If the stone be gypsum, that sediment will weigh 77 or 78 grains; it will have all the properties of common limestone reduced to powder, it will effervesce with, and totally dissolve in a mixture of one part of spirit of salt to two parts water added by degrees till the whole be dissolved. T. C.

Chicory. Succory. Chicorium Intubus.

Extract of a letter from Judge Peters to the Editor.

"In the life time of General Washington, many years ago, he "had frequent correspondence with the Scavans in agriculture, in "Europe. It became so burthensome to him, that at his request "I took it off his hands. I had much intercourse with several of "them on the subject of the chicorium intubus. Arthur Young, "was enthusiastic *for a time*, in favour of this plant. He has hot "and cold fits on most subjects. Both the General and myself "tried this plant as a grass, with no such wonderful effects as those "Mr. Young had pourtrayed. Yet we found to a certain point that "it was valuable. Having long given up my farm to tenants, I am "only a sort of chamber-counsel in husbandry. I reserve 20 or 30 "acres for amusement, and on this small scale continue to try every "thing I hear of, any wise likely to be useful. As a material for "*Coffee*, I have never known the *Succory*, as we call it, or *Chicory* "as it is called perhaps with more botanical correctness. The na- "tive succory I found in this part of the country, was a mean plant. "If without much trouble you could procure for me seed of *good* "native or foreign chicory, I will begin some experiments on its "uses as a substitute for Coffee. Inform me of the method of "treating it for this purpose. I am, &c. *Richard Peters.*'

The Chicory, is a species of Endive; wild Endive: the seeds of these plants are much alike.

In the state of Pennsylvania, though but in a few places, chicory or succory as the German settlers call it, has been cultivated as a substitute for coffee with much success. The plant is sown in beds either drilled or broad cast; and thinned out to about six or eight inches apart. In the beginning of winter they are taken

up, washed, and put into an oven after the bread is drawn. In this state they keep well. When wanted for use, they are again put into the oven after the bread is drawn, and dried till they assume a full brown colour. They are then ground or beaten in a mortar, and mixed with from one fourth to one half of their weight of West India coffee. I have repeatedly drank of this beverage without distinguishing it from common unmixed coffee. In Northumberland and the neighbourhood, and at Williamsport (Pennsylvania) this use of chicory is common. It would be improved, if in the last roasting, the chicory could be roasted with the coffee so as to imbibe the vapour of the latter. The chicory of itself is the best substitute hitherto known.

In England they use (or rather propose, for coffee is too dear there to be a common beverage) as substitutes for coffee, 1st. Roasted Barley. 2ly. The seeds of the yellow water flag, or flower de luce (Iris pseudacorus) 22 Nich. Journ. 70. 3ly. The ockra, which is also a fashionable substitute in the West India Islands. But the German establishments for the manufacture of chicory coffee, and what I know of it by my own experience, leads me to recommend in preference, this plant to all others.

Previous to the capture of Jena, by Buonaparte, there were upwards of two millions of pounds of chicory coffee, exported from that place and Brunswick to various parts of France and Germany.

But whatever may be the use of this plant as a substitute for coffee, it is not to be compared in point of importance to its use in agriculture, particularly as fodder for cattle of all kinds in cases of a dry spring, or summer. It is equally nutritious and more productive than Luzerne, without requiring half the attention.

The first notice I find of the agricultural use of this plant, is in the 6th. vol. of Young's annals of agriculture, p. 48, where Mr. A. Zappa of Milan, enumerates it as one of the favorite plants in the meadows of Lombardy. This was in 1786. In 1787, Arth. Young being at M. Crette De Palleuil's* near St. Dennis, was so struck with it, that he bought 10lbs. of the seed, and sowed it at Bradley, 10lbs. to the acre. In May 21, 1789, he cut it on a small patch, that yielded *at the rate* of upwards of 12 tons 11 cwt. of green fodder per acre, at a time when every other meadow was parched and dried up. On the 24th July he cut the same patch again, which yielded at the rate of 16 tons 4 cwt. of green food: on the 3d of

* The Life of this most useful citizen who died 30 Nov. 1799, may be found in 14 Month. Mag. p. 237.

December, he cut it again, and obtained at the rate of 9 tons 14 cwt. per acre; in all, 38 tons and 9 cwt. of grass. This, on losing three fourths in drying, would have yielded upwards of 9 tons of Hay.

But these experiments being made on a small scale, furnished no criterion for a regular course of husbandry, in which chicory should form a permanent part of the meadow crop; he proceeded therefore in sowing it, till in the spring of 1792, he had $14 \times 60 = 74$ acres, either entirely or partially sown with chicory. The other grasses he sowed with it, were the red clover, and timothy, rib grass, poa trivialis or common meadow grass, and these were sown with the chicory on the principle that as this grass does not tiller, the other accompanying grasses fill up the ground and make a full, close sward. It may be noted, that in England, chicory appears as one of the earliest spring grasses, being from 3 to 4 inches high on a poor soil on the 11th of May: but yet, not so early as the avena elatior the tall oat grass, or the rough cock's foot, dactylus glomeratus. By this time Young had ascertained, 1st. that though a perennial, it will not bear frequent seeding without being impoverished: and 2ly. that it is better to cut it after the first year at least 3 if not 4 times, in the course of the season. In this year he has registered the feeding of $58\frac{1}{4}$ acres of chicory alone, or with other grasses, by means of sheep. Indeed, all cattle, horses, oxen, sheep and swine eat it greedily.

This experiment appears to have turned out very satisfactorily, but it is too long to repeat here. The subsequent numbers of the annals of agriculture contain notices by the editor himself, though few by other persons. In the volume for 1799, I find the following note. "If the reader turns to vol. 28, p. 386, he will find an ac- "count of chicory by Mr. Martin of Northampton: meeting him "this year at the Duke of Bedford's sheep shearing, he informed "me that in the present season he has nothing on his farm, no plant "or crop whatever, that will keep half the stock which his chi- "cory will, though it be four years old."

His account of the French husbandry of chicory may be found in the 2nd vol. of the tour to France p. 62.

In addition to this, I may add, that in the year 1793, Mr. Roscoe of Liverpool, walked with me to see Mr. Wakefield's Dairy farm about $1\frac{1}{2}$ mile from the town.

Mr. Wakefield had sown in 1793 about 3 acres, and cut it 3 times in 12 weeks: the whole was given to 10 heavy working horses, who went through their common labour upon it without hay

or corn. He calculated to feed his dairy of 120 milch cows during the succeeding summer chiefly on chicory, and in the winter on potatoes steamed. He gave me 2lbs. of the seed, which I distributed partly to Mr. John Adlum then of Muncy, and partly to Mr. Samuel Wallis, but I believe they made no use of it.

His mode of steaming his potatoes is curious. A large iron pot is let down into a hole even with the surface of the ground. A fire place is made underneath, and a brick flue at the opposite end. Round the rim of the pot is a wooden kirb about 2 or 3 inches broad. When the water boils, a hogshead full of potatoes (well washed and scrubbed at a trough under the pump) is rolled over the boiler within the wooden kirb. The bottom of the hogshead is pierced full of holes. A loose cover is put on the top. The steam ascends through the holes in the bottom, and in half an hour, the potatoes are boiled. The hogshead is then rolled off and another rolled on. I think he had 3 iron boilers for the supply of his cattle with steamed potatoes. Potatoes were at that time worth about 2s 6d sterling the load of 240lb. washed, or 250 in the dirt. A bushel of potatoes will weigh about 72lb. The average crop of Lancashire and Cheshire, cannot be taken at less than 400 or 450 bushels per statute acre. This is effected by dint of manure laid on at the rate of 10L. sterling an acre, and accurate weeding, which the potatoe crop pays for, and brings the land in heart for 2 or 3 years.

In 1797, that promoter of British Agriculture the late Duke of Bedford, directed a poor field of brushy soil on his farm at Woburne, worth from 7 to 10s. an acre, to be sowed with chicory. The first year's produce supported seven Leicester sheep averaging 22lb. a quarter, per acre, for six months. His grace was of opinion that no other artificial grass on the same land would have equalled this.

Arthur Young says that the Chicorium Intubus grows wild in Suffolk and other parts of England. The Rev. Mr. Muhlenberg of Lancaster says it is a common plant or rather weed, about Lancaster. They both agree that in its wild state, it is not worth any thing. But by long course of cultivation the French, and from it, the English seed, is now a very valuable improvement on the wild succory. The Chicory I have seen growing about Northumberland and in Lycoming county, is certainly not equal to what I saw at Mr. Wakefield's in 1793: In 1797 and 1798 the seed sold in London for a dollar and 5s the lb. T. C.

Some observations on vegetation, and manures, by the Editor.

Agriculture. The art of selecting and raising to the best advantage, those vegetable substances that serve for the use of man.

It is not my intention to enter at large into the extensive theory of this first of arts, or to give a detailed account of practices adopted or recommended by the numerous writers on this prolific subject: but a few *general* observations hitherto seldom noticed in the connection now presented to the reader may furnish more accurate ideas than commonly prevail.

The theory of agriculture relates to I the properties of the plant itself. II. of the climate and soil in which it is placed. III. The mode of accelerating its growth and encreasing its size

Writers on agriculture, ignorant for the most part of the physiology of animals as well as vegetables, have usually considered and treated of plants as inanimate beings: they are not so.

Every plant is the production of an organized seed endued with the property of vegetable life, and of being acted upon by appropriate stimuli. This vegetable life is originally excited and subsequently continued by the application of what may be called *natural* stimuli, much in the same manner as in animals. Thus the pollen of the pointal received by the chive, and thence propagated to the seed vessel, impregnates the seed, and excites the action of the living fibre, which afterwards proceeds according to the laws of organization peculiar to each plant. This action is continually renewed by the application of vegetable food by means of which the germ is dilated till the plant arrives at its full growth. All this is perfectly analogous to the impregnation of the animal germ in the ovarium, and its subsequent growth to full age and size.

In animals, the muscular fibres have the property of contracting on being irritated. *Irritability* as it is called. So have vegetable fibres. The sensitiveplant, the hedasyrum, the dionæa muscipula of Carolina, the phenomena of plants growing in a dark place and turning to the light, are proofs of this, if not of voluntarity. The separated twigs of hedasyrum, are irritable, like a separated muscle. Mr. Howard has lately discovered the same property in the pollen, on the application of alcohol. (Trans. Linn. Society of London.)

Animals have feeling, perception, or *sensibility*, and the power of voluntary motion. So have plants.

The facts adduced by Percival, Smith, and Darwin, and the whole

class of phenomena relating to their search of food, and the propagation of their species seems to put this beyond reasonable doubt. To which may be added the habits and customs of the parasite plants.

Animals though perfect in all their parts, may be stinted in their growth by too small a quantity of food, and by other means; and this diminution will affect the size of their offspring. The case is precisely the same with plants. By plenty of food and favourable situations, animals may be encreased in size. So may vegetables. By breeding from selected couples of a large size, the size of the animal offspring is encreased. Hereon was founded the successful practice of the greatest cattle breeder in England, Mr. Bakewell of Ditchley; and the same set of experiments has been repeated with equal success on plants by Mr. Cooper of New Jersey. Mr. Bakewell encreased the flesh on particular bones of his cattle, and propagated this propensity. Mr. Cooper has in like manner propagated not merely encrease of size, but encrease of size in particular parts of the plant, and propensities to earlier vegetation.

In animals, appetite may be provoked, and digestion assisted, by the artificial stimuli, of what physicians call *Condiments*, salt, pepper, wine, acids, bitters, &c. Such also is the property of vegetables. Their hands, mouth, and stomach, are in the soil; and by the application of artificial stimuli, such as lime, common salt, alkalies, plaister of Paris, &c. their roots may be excited to want, to seek, to take in, and to digest more nutriment than they would otherwise use.

Animals may be surfeited with too much nourishment. So a plant will die if set in a mere dung-heap. Animals may be poisoned. So may plants. Every metallic combination for instance, except oxygenated and carbonated iron, and calx of manganese (and lead?) in small quantities, being poisons to the vegetable.

By the artificial stimuli of condiments, animals may be excited too much, and indirect debility will ensue. So is it with plants. In like manner, excess of these artificial stimuli will take away their beneficial effects, as half a pint of wine may assist, when a bottle will injure digestion. Thus, from the experiments of Sir John Pringle, and Dr. Watson, (Bishop of Landaff) it appears that a small quantity of common salt is a septic to the animal fibre, and a manure to vegetables, while a large quantity, is the domestic antiseptic of cookery, and destroys vegetation altogether. So in the

experiments of Judge Peters, two bushels of gypsum will produce a luxuriant crop; 6 or 8 will prevent it.

In animals, when parts of muscular or other fibres, are weak, diseased and dying, artificial stimuli can be applied to excite an action in the living and healthy parts, by which the dead are separated and sloughed off. So in plants, the artificial stimulus of those substances which are not manures in the sense of affording nourishment to the plants, but only as exciting a stronger and more healthy action in the living fibre, will kill the weak and diseased roots, while they invigorate the more healthy. This is the mode of action (in part) of lime, gypsum, salt, &c. usually classed among manures, but which do not enter into the composition of the plant itself.

Animals are resolveable into gasses, lime and phosphoric acid. There is no peculiar animal earth. The phenomena of marine animals, the experiments of Vauquelin on the production of lime in the hen, and some other facts, make it probable, that the lime of the bones, as well as their phosphoric acid, is the product of animalization.

Vegetables are resolveable into gasses and fixed alkali by fire: by putrefaction their alkali is either decomposed, or escapes, for no fixed alkali is found on the incineration of vegetables which have undergone compleatly the putrefactive process. Both vegetables and animals contain in their fluids accidentally, unessential quantities of iron, manganese, and neutral salts. Thus the blood contains iron, albumen, mucilage, the serum, urine, uric and phosphoric acids with bases of lime, soda, volatile alkali. So in plants, nitre is found in borrage, in nettles, &c. and oxalates in some. Hence it appears, that the essentialy component parts of animals and vegetables consist chiefly of two or three gasses.

Again. Animal fibres are made from plants. So true is the scripture exclamation that all flesh is grass! An ox and a sheep are made up of vegetables, and so are we who devour them. Nothing is nourishment to an animal, but what was originally a vegetable. In like manner nothing is nourishment to a vegetable but what enters into the permanent composition of a vegetable. We find large plants grow in pure sand (Vanhelmont), in sand and clay, in common clay, in limestone, in limestone and sand, limestone and clay, and in all the combinations of these common earths, nay even in sulphur, in shot, in pounded glass, but we do not find that these earths or either of them, are any permanent and essen-

tial parts of the composition of a plant any more than of an animal. In a human body of 200lb. weight, we may find about the fourth or fifth of an oz. of common salt, and we may *perhaps* find in clover the same proportion of gypsum, but these are accidental parts of the composition.

More accurately. When a vegetable is decomposed by means of fire, in close vessels, we procure, 1st a considerable quantity of water. 2dly. Pyroligneous acid or an empyreumatic vinegar. 3dly. On the top of these and mixed with them, is a quantity of strong oily matter that smells of tar and smoke. 4thly. a great quantity of carburetted hydrogen gas, to wit about 50 quarts to the lb. avoirdupoise of fine saw dust. All woods, and (I believe) all vegetables, furnish it in some proportion. 5thly. A 5th or 6th in weight of charcoal, and nearly equal in bulk to the vegetable itself; of this about 90 parts in 100 are frequently pure carbon, when well burnt and freshly made and weighed. 6thly. Alkali: inland plants furnish the alkali of potash; marine plants generally furnish the alkali of soda. The alkali of potash obtainable from the green woods usually employed for the purpose, does not exceed one part in 16 or 1800parts. 7thly. earthy salts and iron, in minute and accidental proportions.

Now, The water, is hydrogen and oxygen.

The pyroligneous vinegar, is carbon, hydrogen and oxygen.

The oily matter is carbon and hydrogen.

The carburetted hydrogen, is carbon and hydrogen.

The charcoal is nearly pure carbon.

The alkali, is an oxyd of a metal.

The iron, or manganese may be accidental, but one or other is almost always found, though in minute proportions.

Some vegetables, as the farinaceous that contain gluten, and the succulent tetradynamious plants that contain albuminous matter, furnish also azot. So do mushrooms, trufles, and morells, which on distillation give out volatile alkali, the base of which is azot. But the vegetables that furnish azot, are exceptions to a general rule. Lime also in very small quantities, is frequently found in vegetables, but nothing tends to induce us to regard it, as other than an accidental substance.

The result is the same, when vegetable matter is decomposed in the moist way. Thus: let us take the case of a Distillery, and consider the process that goes on there. The bruised grain is mixed with water: then yeast, (that is, carbonic acid gas enveloped in mucilage) is put to it. The gas acts upon the grain, and decompo-

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sition, and new compositions take place. Great quantities of carbonic acid gas are evolved: alcohol is formed: then vinegar, which is alcohol united to oxygen. What do these products amount to, but carbon and hydrogen, and the oxygen imbibed from the atmosphere? For every drop of vinegar is made at the expence of a particle of alcohol united to a particle of oxygen.

In the case of the decomposition of animal substances, whether in the dry, or the moist way, no acid appears: we get azot, a fetid animal oil, swimming at the top of a volatile alkaline liquor, and sometimes concrete volatile alkali, or carbonat of ammonia comes over. The retort contains an animal charcoal, consisting of azot, carbon loosely combined, the base of the prussic acid, and if bones be used, phosphat of lime.

In this case, the azot, the lime, and the phosphorus, seem to be new combinations, the result of animal organization modifying chemical affinity. There are many districts of Pennsylvania, perhaps the best pasture land in it, that do not contain a particle of limestone. Such for instance as a great part of the county of Luzerne and the beech country comprehended between the north east branch of Susquehanna, the New York state line, and the Delaware. There is no finer grass country; but limestone is rare throughout the greatest part of this space. A calf bred up there, will have *bones*, that is phosphat of lime: his flesh will yield *azot*, either by distillation, or by the nitric acid. Where does he get it? The soil contains none; the grass on which he feeds contains none, but the ox is chiefly composed of azot and phosphat of lime!

Hence it appears that about 99 parts out of a hundred of vegetable matter, consist of carbon and hydrogen of which the carbon far exceeds in quantity.

Hence also, the pabulum or food of vegetables, can only be carbon and hydrogen, or those substances which are easily decomposeable into carbon and hydrogen.

Hence animal matter is the best of manures, because, the carbon it contains is more easily disengaged, and the substance more easily decomposed than even putrescent vegetable matter. Hence it is that in steel furnaces and in case-hardening, animal charcoal is thought to aid the operation; the carbon of animal, being more easily separated, than the carbon of vegetable charcoal.

Hence we learn to distinguish, manures of *nourishment*, from manures of *stimulus*, and from *mechanical* manures; and we are taught that every vegetable and every animal substance when decomposed, furnishes pabulum to vegetables; and that every such substance

so decomposed is a manure of nourishment, and that nothing else is or can be. It may be taken for an axiom, that from man to a cabbage or a lichen, nothing can be converted into nutriment for the living fibre, but what has been a permanently component part of living fibre before.

Other properties of vegetables there are, *similar* (rather than analogous) to those of animals, which the necessary brevity of a short essay, will not permit to be detailed at length. It may be observed however, that plants like animals may be transplanted from one climate and soil to another, provided the difference be not very great, and care be taken to accustom them gradually to the change. Indeed, vegetables like animals will accustom *themselves* to the change in a generation or two, provided the difference be not above 8 or 10 degrees of latitude or of mean temperature. The range is not yet ascertained.

On the preceding properties of vegetables, and their analogies to animals, may all the agricultural doctrine of manures be well founded. These analogies have been remarked by others, but their application in this respect has not been heretofore sufficiently observed.

Animals *differ* from vegetables in having a more extended sphere of locomotion. The animal (cases nearly zoophytical, excepted) can move the whole of his body from one place to another ....a plant can only move its root-fibres and its branches. The *convolvuli*, and other parasite plants, are in some degree exceptions; but the general rule is, that the immovable centre of a plant's situation is the place where the germ falls, or the seed or plant is set with intent that it should remain. Hence the use of that kind of manuring which consists in the admixture of soils of various depths and adhesion, for the mechanical purpose of keeping the plant steady.

II. Of the climate and soil.

No experiments have been made to ascertain with precision the bounds of latitude or temperature which prohibit the naturalization of exotic plants. In France, YOUNG has marked the lines of the maize and the vine culture.....In this country maize grows tolerably well from lat. 42, and beyond it to Georgia. Wheat is not so good and productive south of Virginia, as in the middle states. The latitudes of cotton and rice, are not yet exactly ascertained. Coffee has not yet had a fair trial in our southern states, nor the sugar cane. Much indeed yet remains to be done in this

respect, and much is doing by the British government in the West Indies.

Agriculturists have many vague denominations of soil, such as clay, loamy, marly, sandy, limestone, limestone gravel, sandy gravel, stoney, poor light soil, rich black soil. These aretolerably descriptive in a general way; but as the theory of the art improves, we shall need more accuracy. Of the primitive earths, none need be noticed under this section, but silex or sand; argil or clay: and calx or lime. The others have never been yet found in sufficient quantity to produce any notable effect, except in the hurtful quality of magnesia when combined with lime, as 2 to 3 first noticed by Mr. TENNANT. It is evident that for the mechanical purpose of increasing or lessening adhesion, supporting the plant, and admitting its fibres to shoot more freely, clay, sand, and limestone are mutually manures to each other; acting mechanically by their mixture. Thus in Cheshire and Norfolk, in England, the clay and marl pits furnish an excellent and permanent manure to the sandy soil above; and assist moreover in retaining manure and imbibing moisture.

But it is not merely the mechanical mixture of soils that may be useful; for the experiments of M. D'ABRCET and M. FARONI have shewn us, that in the temperature of 100° of FAHR. different earths have different capacities for retaining moisture; so that by judicious admixtures, this valuable property in soils may be increased or diminished; and as none of the earths are found perfectly pure in soils, (clay, for instance, retaining 66 per cent. of sand without losing its distinctive character) tive character) a field is opened for ascertaining this property in different admixtures and combinations. For Mr. WEDGWOOD discovered that earths would chemically combine in the moist way.

Besides the tenacity of soils, and their capability of retaining moisture, their *depth* is also to be considered by the cultivator. Some plants have long tap-roots, such as rhubarb, liquorice, carrots, parsnips, madder, &c. These are evidently unfit for any soils, but of loose adhesion and of considerable depth. Equally preposterous would it be to use a soil like the Genesee flats, of 20 feet deep of light, rich mould, for grasses that spread upon the surface. Again, where soils are naturally sandy, dry, and arid and the climate warm, plants should be selected, whose roots penetrate deep and beyond the influence of atmostpheric evaporation. Thus, in this country as in the south of France, Lucerne, *(medica)* and

chicory *(cichorium intubus)* would be luxuriant where no other grass would grow.

III. I come now to consider the mode of accelerating the growth and increasing the size of plants.

This is done by *manures*. Hitherto, every substance added to soil or to the plant while growing, which effected, or was meant to effect these purposes, was called a manure. But, from what has been said, manure ought to be considered in at least four divisions. 1. Manures of nourishment. 2. Manures of stimulus. 3. Manures of moisture. 4. Mechanical manures.

Manures of nourishment. Five different theories have been started on this subject, the pabulum of vegetables.

1. Practical men have for ages discovered the use of dung in agriculture, and hence the common and oldest theory was, that the juices of decomposed animal and vegetable substances in the gross, were the chief pabulum of plants.

2. VANHELMONT'S experiment suggested *water* as the pabulum, but although some plants will live, none will flourish in mere water....The French experiment of the decomposition of water, and the discovery of the excretion of oxygen, give countenance to the opinion that water, though not *the* pabulum, is decomposeable, and is a pabulum; furnishing hydrogen: and it is also a component part of the plant even as water. The curious experiments of M. Braconnot add strength to this opinion. It is not yet known whether plants can decompose azot, but I am strongly inclined to suspect this substance to be a compound, for we have no fact to shew that animals absorb it from the atmosphere.

3. Dr. HUNTER, of York, in his *Georgical Essays*, persuaded the world for some time, that oil was the pabulum of vegetables. But neither his theory nor his practice succeeded.

4. Dr. PRIESTLEY, who had more right to form theories and conjectures than any man living, (because he furnished more facts of extensive application in chemical philosophy than any other man,) suggested that *phlogiston* was the pabulum. Some experiments of ARTHUR YOUNG, made in consequence of this supposition, tend to support it. But though in all probability *inflammable gas* may be converted into nutriment to vegetables, yet it is far from being true, that this is the only gas which can. The gasses that escape from a dung-hill contain much carbon, azot, and ammonia, as well as various stimulating saline compounds. We know too, that electricity, and the galvanic fluid, seem to aid ve-

getation to a certain degree: but the action of these fluids is more satisfactorily accounted for, on the doctrine of stimulus, than of pabulum. That oxygen is not nutriment, is clear, from its being an excretion of plants in a healthy state, and in vigorous action, under the influence of the sun, as Dr. PRIESTLEY, and afterwards M. INGENHOUZ discovered. Hence, although fluid manures may contain the elements of phlogiston, or the combinations of phlogiston, this latter cannot of itself be taken as the only food of plants. Both plants and animals are resolvable into gasses of which phlogiston may be a part, but there is something else which feeds and dilates the muscles of animals, and the leaves of trees, for they furnish something else.

5. Dissatisfied with former theories, Mr. KIRWAN has proposed *carbon* or charcoal as the food of plants; and declares his opinion that if charcoal could be rendered soluble in water it would be the most efficacious manure. It is true, that charcoal and carburetted hydrogen, are found in the incineration of all undecomposed vegetables, but they contain also alkali, oxygen, and nitrogen, &c.; nor is there any fact to prove that charcoal (or the oxyde of carbon) is either soluble in any liquid, or taken up as charcoal by any vegetable, or decomposed by any natural process; soot as a top dressing is a tolerable manure in England, but its use may be accounted for from the saline substances it contains. From every fact hitherto known, the pabulum of vegetables, appears to be exhibited to plants generally in the form of a *liquid*. Hence, whatever theory of ingenious speculators be adopted as the simple and homogeneous pabulum of vegetable bodies in a living state, the old theory and the old practice must, and ought to prevail, namely, that the only manure of nourishment to be depended on, is dung, *(i. e.) decomposed animal and vegetable substances*; which contains within itself every substance that theory has hitherto assigned as the food of plants, ready to be afforded gradually, by the continual decomposition of the various compounds which the dung contains: and although it may be of use by dung-heaps to aid this decomposition, yet even in an undecomposed, or partially decomposed state, this gradual decomposition amounts in the end to the same thing. This is applicable to ground bone, woollen rags, horn shavings, &c. All the difference is that *time is gained* by the artificial and complete decomposition of these substances.

Manures of stimulus. Whatever accelerates the growth, or encreases the size of plants, and does not actually enter into the com-

position and substance of the vegetable, can only be considered as a manure, by stimulating the healthy fibre of the plant, by destroying the dead and decaying fibres, and by assisting the decomposition of undecomposed animal and vegetable substances dispersed through the soil. It is thus that *gypsum* or plaister of Paris acts, being the most efficacious septic among the neutral saline substances. Of these manures of stimulus, none are as yet in common use, but lime, gypsum, and common salt.

Lime, is limestone deprived of its water and carbonic acid amounting to 44 per cent. by fire. In this state, its stimulating powers are obviously much greater, than in its natural and neutral state of limestone. But even pounded limestone is a promoter of vegetation mechanically, on clayey and sandy lands; and this earth appears to be a specific stimulus to white clover, and perhaps to the potatoe. Hereto may be referred the rubbish of old buildings, and marl, which is clay about one half of limestone.

Common Salt. This, until the duty of two thousand per cent. in England, was a very common manure in Cheshire; the facts relating to it, in this point of view, are collected in WATSON'S *chemical essays.* In this country, Gypsum is much cheaper.

Gypsum, plaister of Paris, *vitriolated lime*, or *sulphat* of lime. This has not been certainly found in any plant, but by M. MODEL, accidentally, in rhubarb, (*Journ. de phys.* vol. 6. p. 14,) even this I suspect to be a fallacy; for the characters of gypsum were not then well ascertained. About two bushels per acre to clover or corn seem to be a full quantity. It attracts the moisture from the air, and dissolves gradually when strewed on the ground. It is brought here from France and the bay of Fundy, and has also been lately found in New-Hampshire, and on lake Erie. There is also some in Maryland on the Chesapeake, about one hundred miles below Baltimore, and throughout the Genesee country, and on the waters of the Chippawa. As it is not a component part of any plant, either in whole, or in its own component parts, it cannot act upon healthy vegetables but as a stimulus, and upon diseased and dead ones, by its septic power. Experiments remain to be tried as to other manures of this description.

Gypsum particularly deserves attention, considering that it has effected almost a complete revolution in the agriculture of Pennsylvania. Many thousand acres of land hitherto barren, have been converted into excellent pasture ground, by its surprising influence. Even the products of land, tolerably good, have been in some in-

stances doubled by using it. The theory of its action was not understood. Judge PETERS of Philadelphia, who first collected the opinions of our farmers, on the subject of the gypsum as a manure, ventured to suggest, that the vitriolic acid was the fertilizing principle of this manure: But Mr. Priestley of Northumberland, has given this opinion a fair trial, both by means of sulphur, and of sulphuric acid, in all proportions, without the slightest appearance of success. We shall have therefore as I think, to recur to the theory first advanced by myself in the year 1793, that it acts as a septic to dead fibres, and as a stimulus to living ones.

Manures of moisture and Mechanical manures. Their action in giving *depth* by new addition; in giving *tenacity* by mixture, as clay with sand, or *vice versa*....in giving *capacity to retain moisture*, on the principles suggested by the experiments of FABRONI and D'ARCET, is too obvious to require further elucidation.

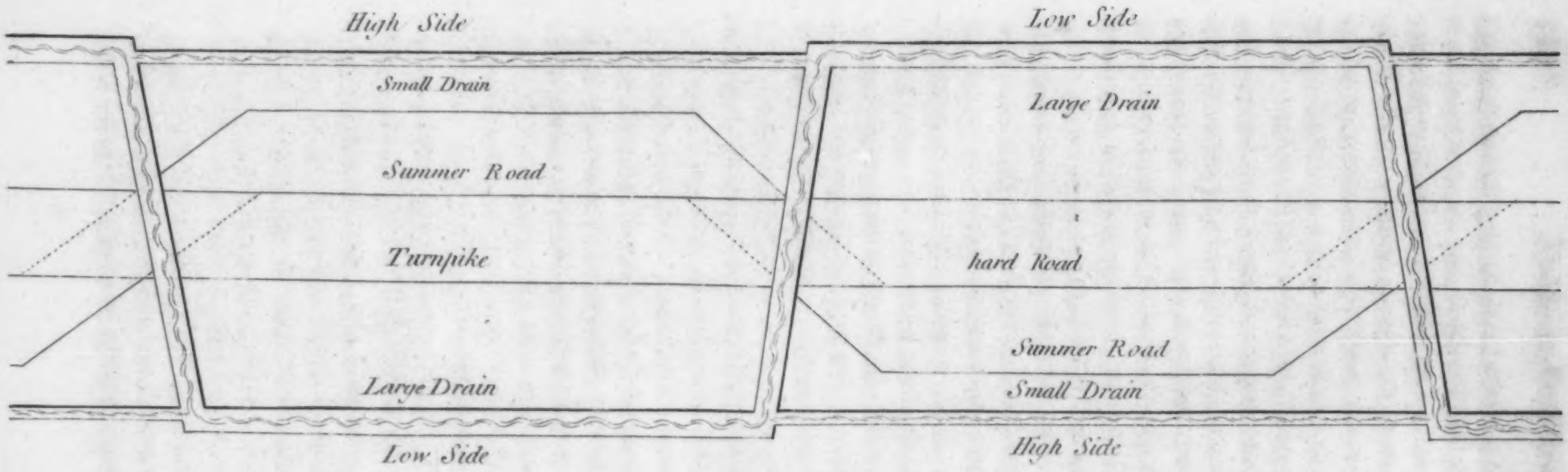
Such are the ideas that occur to me as throwing some light on the theory of this complicated and most important subject, and suggesting the *rationale* of the application of manures, in cases not hitherto well understood. T. C.

TURNPIKE ROADS.

To the Editor of the Emporium.

If turnpike roads and their drains, were to be formed at first according to the drawings, (See Plate) making the summer road to cross the paved road at every change of the surface of the country, so as to keep the summer road always on the highest side, with a small drain along side of it, (though it may do without any, as it has but little water to carry off) and to keep the large drain on the lower side, crossing at every change of surface of the country, until it can be let entirely off from the road—In such case, summer roads could be kept good at a small expence, as they would never be washed with the main body of water. The drains on the lower side could be kept from washing, by throwing in stones. But where an attempt is made to keep up a summer road on both sides, both become drains for the water, and in a short time both become inevitably lost; for a drain makes a bad road.

It is better to have one good summer road to cross the paved road often, than to have none at all. The summer road thus ma-


High Side
Low Side
Small Drain
Large Drain
Summer Road
hard Road
Turnpike
Summer Road
Large Drain
Small Drain
Low Side
High Side

Bank
Form of Surface
Lower Side
Small Drain
Large Drain

naged will be much the cheapest, for earth cannot be changed into any thing else by travelling on it, whereas the stone pavement is continually changing into earth, and requires expensive repairs. By such an improvement as is here suggested, many thousand dollars might be saved to stockholders. The summer road on the Lancaster Turnpike (and on others also) is already almost ruined for want of necessary precautions.

While on this subject, I beg to observe, that on my travels I see it frequent in opening new roads, to clear the lower side first for the carriages, and to allow the water to run along the down hill rut: thus the road soon becomes dangerous, and repairing it expensive: whereas if the passage for carriages was first opened on the upper side of the scite of the road, and the water confined to run along the up-hill rut, until it would be conveyed away, the road would ever after be kept in repair, for not more than one tenth part of the expence otherwise incurred. If you think the above worthy a place in your Emporium from one of your subscribers, it is at your disposal. I am &c. O. E.

I shall always think the communications of this correspondent worthy a place in the Emporium. To the preceding obvious and sensible remarks, I had intended to have added my notions of the chief cause of the destruction and want of profit of turnpike roads. I am persuaded, that carriage can be cheaper performed with 3 horses to a team than with four: cheaper with two than with three: and cheapest by means of single horse carts. I have not room in this number to insert the facts that induce me to think so, but I will collect them for the next. No turnpike can stand the wear and tear of five horse waggons, and be profitable to the stock holders. T. C.

NOTICE TO CORRESPONDENTS.

Some of the subscribers to the Emporium, have expressed apprehensions lest it should become a *political* publication: others have expressed disapprobation at the editor having supported the opinion, that manufactures should be encouraged at the expence of commerce.

As to politics: I hope there is no subscriber to the Emporium incapable of distinguishing between the petty discussions of party politics, and the great questions of political economy! If there be,

explanation would be useless to him. Whatever my politics may be, *I have none in this work.* As to the questions of political economy—what are the principles of public action (under whatever rulers, or whatever form of government) that lead most directly and permanently, to national wealth and national power—and are most consistent with national security and national prosperity—I shall continue to discuss them. They have been for some years, and still are under discussion among the ablest statesmen, and the best informed writers of Europe, and they are still unsettled. In this country, they were never touched, until my essay of 1799, and a brief view of the expedience of protecting foreign commerce, published soon after, by Dr. Priestley. At that time we were alone in our views of the subject. At present I am fully persuaded, that a decided majority of the literati of Great Britain who have turned their attention to these questions, are with us. In this country, the topics have been too little discussed, to allow any public sentiment to have been formed. The popular opinions—prevalent among those who have not read or thought much on the subject, are greatly adverse here, to what I think a correct system: but who is it that says they ought not to be discussed? can he be a friend to science, or a friend to his country? Ganilh's book, evidently published in opposition to Montgaillard's, has been reviewed with much encomium in the best of our miscellanies, the Port-folio, and with much laboured panegyric in Mr. Walsh's Review. What, is it a crime to dissent from their opinions?

The present series of the Emporium, professes to give, a connected set of essays on the leading manufactures of Europe likely to be of advantage in this country, taking them up one by one. But as all readers cannot feel interested in any one manufacture (unless men of general science) it is proposed to fill up at least a third of the work with miscellaneous essays. I greatly doubt whether I can make this an entertaining work. I fear I want qualifications: still less can I undertake, that all the opinions I may advance, shall meet with the full assent and approbation of all my readers. But this I can promise, that when I have gone through my twelve month's editorship of this work, it shall not be thrown aside, or torn up for waste paper. Those who have it will keep it, or I shall not answer my own expectations.

But the very design and intent of the Emporium, is, to give information on those manufactures which it is worth while to attempt in this country: every such manufacture, if it succeed, will take

away from the necessity of European importation. Those who think we ought to depend on Great Britain, for all our necessary comforts and luxuries, and raise nothing, and export nothing, but raw materials for British traders to work up and sell to us in a new form, will doubtless be the advocates of foreign commerce, and of all its concomitants: they will not approve of such a work as this, or wish success to any home manufacture, which will so far supercede the necessity of foreign importation. If readers of this description disapprove of the principles advanced in this work, I cannot help it: but most assuredly, a work that professes to aid the exertions of *home* trade, may without impropriety be permitted to suggest, that the benefits of *foreign* trade have been overrated; and allowed to state the facts and arguments that support such an opinion.

But the questions of political economy are really of so much national importance—they require and imply so much important fact to elucidate them—they are here so new—and every where so unsettled, that I feel ashamed of this apology. I shall be glad to receive condensed and well-considered replies to my own opinions. I have been collecting, some statistical and financial facts relative to Great Britain, France and this country, which I shall give in the next number.

I have read the first volume of Mr. *James Cutbush's* manual of chemistry, but I have not yet seen the second. There are some slight inaccuracies in the first, but it is a useful compendium; containing as much fact in as small a compass, with as little unnecessary matter, as any compilation I have seen for some time. I shall be glad of an opportunity of expressing myself as favourably of the second volume; which I dare say I shall be enabled to do very truly.

I have read the first part of a treatise on distilling, by Mr. *Harrison Hall*, of Philadelphia. If a few pages of chemical disquisition were omitted, and some practical directions given on the use of the hydrometer, it would be the *best* book I have seen on the subject. Indeed I consider it such as it is. It supercedes a great deal of what I had to say on this manufacture, but I can make some additions when the proper time comes.

I have received the description of Dr. Allison's machine for spinning wool, which shall have a place in the next number of the Emporium.

PHILADELPHIA, June 16, 1813.

DEAR SIR,

I have to express to you my thanks for the honourable mention you have made of my late exertions in the first number of your Emporium. Perhaps I could have wished, if you will excuse the observation, that the article had been a little more accurate. I have rendered platina malleable, which is a chemical process, but to work it up afterwards into spoons, &c. &c. is the business of artists, and mechanics. Our wags will say, "so the Dr. has turned spoon-maker at last," and they will have your word for it.

You also mention as a general, and apparently steady thing, that the specific gravity of my platina is 19.7—which happened to be the specific gravity of the *ill hammered* specimen you took with you. It generally weighs 21.5, and I have had several pieces of a specific gravity of 22.5. I must repeat on this occasion, that great specific gravity is not absolutely a proof of purity. A piece of pure platina of 19.5 may be hammered into a specific gravity of 23. and a less pure, but better hammered, that is compacter piece, may exceed in specific gravity a piece more pure.—We even know that the specific gravity of brass is greater than that of pure copper, though the specific gravity of zinc is inferior to that of copper; which proves that greatest density, and compactness of a substance—on which its specific gravity depends, does not necessarily imply its greatest purity.

As the article stands it gives the impression, that I only do what Mr. Cloud did before, but better. The fact however is, that Mr. Cloud, whose merits I well know and fully acknowledge—does not seem to have intended more than to produce a cabinet piece of the greatest possible purity and specific gravity, and he has done so: but I have first rendered platina malleable in this country, by means of a process, which admits being executed on a *large* scale, and which, I hope, will become beneficial to the arts, and to society.—Pieces have been made of the weight of two pounds, and upwards. Sheets have been rolled of thirteen inches square, and vessels of platina are now making, and in preparation, which will hold from twenty to thirty gallons.

The method I use is not the one you describe, and which could not be executed in the large way with safety, accuracy and dispatch. I have found hints of it in European publications, but I believe I

have considerably improved it.—You shall have a full account of it after some time, together with some experiments and observations on Platina, which, perhaps, you will not find uninteresting. I am no secret monger; (as you say manufacturers always are) but, since no body would choose to refund me the by no means small expences I have incurred in unsuccessful trials, it would perhaps be carying liberality too far to enable others at once to place themselves on my shoulders.

Many manufacturers, who have improved their processes, I think might plead the same observation in justification of their conduct, when desirous to keep their knowledge rather to themselves, or to impart it only to their children, than give it to the world at large. The patent law seems to sanction the principle that they should benefit by their labours. Why then should a term of reproach attach to individuals proceeding on the same ground?

I have also succeeded in giving the metallic lustre to Pottery by means of Platina, the shades of which may be varied at pleasure, and some other applications of malleable Platina in the arts, are contemplated, of which you shall be informed as soon as their usefulness has been practically ascertained.

Political economy being my favourite science, I have read with particular attention, and interest, the pages relating to it in the first number of your Emporium, and it is with some regret that I perceive you have adopted, and endeavour to give currency to, a train of ideas, in my opinion erroneous, and the prevalence of which with too many, has already produced a vast deal of mischief. That they are both erroneous, and pregnant with evil, appears to me, after much, and repeated reflection, so unquestionably true, that I should not despair, in fair and liberal discussion, to convince Adam Smith himself of it, whom, I know, you have in many points on your side.

If, as a lover of truth, you will receive in a friendly manner, and give a place to in your next number, a few observations addressed to you, as such, on this subject, I shall forthwith commit them to paper, and I intend in this case to examine every position in your political arithmetic together with the arguments intended to support them.

An elementary *popular* treatise on political economy is a work which I conceive much wanted in this country, which I contemplated to write, and in which I have made no inconsiderable pro-

gress. But circumstances have obliged me to defer the full execution of the task to a more propitious moment. I remain, &c.

Thomas Cooper, Esq. Carlisle. E. BOLLMAN.

Upon this letter I have to remark;

That I am well aware of the fact, that the specific gravity of metals is encreased by hammering: but I doubt whether hammering alone will bring platina from 19,5 to 23, though I know that mercury is encreased by congelation from 13,5 to 15,6.

I have not ventured to say that the process I describe, is the same with Dr. Bollman's. I understand it to be the process hitherto commonly used in France and England. Achard's method with arsenic I have tried; but heat alone will not drive off the arsenic. Whenever Dr. Bollman finds it convenient to publish his process, I shall be very glad to make the Emporium the mean of communication.

I have said, manufacturers are secret-mongers. They are so; and they have a right to be so, if they think fit. I know of no obligation that calls upon them to disclose those secrets upon which their subsistence may depend. When they conceal, and make secrets of the common and usual processes of their manufacture, they do not act liberally: when they conceal processes peculiar to themselves, or not generally known, they exercise a caution, which may frequently be a duty. It is no term of reproach. The public are obliged to those who communicate knowledge of any kind; and every man who has lived long, and much in the world, and who has observed much, has much to communicate that the public will be the wiser for knowing; but there is no obligation on him to do so.

Dr. Bollman is fearful lest the wags should say he has turned spoon-maker. What! was not Prince Rupert a manufacturer—the Marquis of Worcester an engineer—the Duke of Bridgewater a canal-digger—the Duke of Norfolk and Lord Dundonnald manufacturers of coak and coal tar? Was not Sir Richard Arkwright a cotton spinner—Wedgwood and Bentley, potters? Are not Boulton and Watt spoon-makers? Does not Dr. Wollaston manufacture platina spoons? Tell me the men of Europe of whom their country has more reason to be proud, than Watt and Boulton and Wollaston? Lord Loughborough was right, when he said in debate, that weighed in the balances against such men as Boulton and Watt, Sir Richard Arkwright, the duke of Bridgewater and Wedgewood and Bentley, the Lords and the Commons would kick the beam. Dr. Bollman need not be ashamed of company in all respects so truly honourable. I should be glad to have discovered, as Dr. Bollman appears to have done, a method of manufacturing platina easily and cheaply into spoons or any other article of use or ornament, from the boiler of a steam engine to the spoon of a galvanic, or the crucible of an analytical chemist.

Dr. Bollman differs from me, in my notions of political economy: I am glad of it. I shall have an antagonist worth contending with. Whenever Dr. Bollman will send me his communications on this or any other subject, they shall be treated with the attention his talents have a right to claim. T. C.